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PHARMACEUTICAL CONTAINERS AND THEIR DURABILITY

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PRIOR to the development of mass production methods in the manufacture of drugs and pharmaceuticals the durability of the glass container was comparatively unimportant and little attention was given to the subject. The existence of this condition was due primarily to the fact that the distribution of prepared pharmaceutical preparations was not widespread, as each individual pharmacist was of necessity both the manufacturer and distributor and the only durability problem encountered was, in the majority of cases, the occasional development of weathering. Today however, due to the large production of varied pharmaceutical products and their widespread distribution the question of the durability of the glass pharmaceutical container has become of paramount importance to the glass and pharmaceutical manufacturer.

The phases of the glass durability question that are of primary interest to these two groups are: (1) Weathering, i. e. the development of surface films and deposits during the storage of the empty container; (2) Spalling, i. e., the chipping and cracking of the glass surface during washing or sterilizing treatments; (3) Solubility, i. e., the development of chemical reactions between the inner glass surface and the contained material during the life of the complete package. While these three phases are related and closely connected in their theoretical aspects, the practical importance of each phase when considered commercially is quite different.

As the manufacture of pharmaceutical containers is mainly contract work the glass manufacturer usually schedules his production in such a manner that the bulk of the contract is made up at one time. The finished ware is then placed in storage in the glass manufacturer's warehouse for periods depending upon the demand from the consumer. The prevention of weathering during storage therefore is usually the glass manufacturer's problem and as a result of his experience and research, he is in a position to apply the proper preventive measures. At times however, the consumer will store the ware, and if uninformed, as is usually the case, on the proper methods of preventing the development of weathering, he will encounter difficulty. On complaints of this type, if it can be shown that the glass composition and properties are not at fault, the consumer is usually instructed in the proper methods of storage. The development of weathering during shipment to tropical climates, storage in tropical climates or during shipment by boat is much more serious, as it is often impossible to practice the necessary precautions. In these cases the best method of preventing weathering is by using, as far as is practicable, ware that has been made from an exceedingly durable glass composition.

Fortunately very few pharmaceutical containers (excepting of course, ampoules) are subject to severe washing or sterilizing treatments. The milk bottle, for example, is washed and sterilized many times during its life while the pharmaceutical container if so treated undergoes this procedure only once and then under carefully controlled conditions. When spalling does occur it is usually caused by the lack of suitable control of the sterilizing or washing operations.

This lack of resistance towards weathering and spalling was largely a fault of the earlier machine-made bottles which were produced from soft glasses of comparatively simple composition. As a result of the investigations of A. E. Williams, K. L. Ford and others in America and W. E. S. Turner and his co-workers in England on this subject, in addition to the increase in the complexity of glass compositions due to the demands of the higher speed bottle making machinery, the glass manufacturer has been able to improve his product to such an extent that weathering and spalling troubles are no longer such a serious problem. Of much greater importance is the problem of the "solubility" of the glass.

While cases of chemical reaction ("solubility") between the inner glass surface and solid pharmaceutical products containing materials such as potassium carbonate do occur, their frequency is relatively small compared to reactions involving liquids and glass surfaces. It is this latter type of reaction that is of greatest concern to the container and pharmaceutical manufacturers; for while the products of these reactions, i. e., the materials released from the glass surface, are not, when considering the type of glass used for containers, in any way injurious to the health, their effects are such

that a decomposed glass package lacks sales appeal or becomes sub-standard material. For example, the alkali liberated from the glass may cause the development of an off taste and odor, or it may attack the cap liner and cause discoloration and leakage. The suspended material presents an unsightly appearance and may often suggest lack of care in the preparation of the pharmaceutical. With some preparations, the liberated alkali may cause a decrease or increase in the strength of the material and in many cases the addition of the material from the glass surface may prevent the product from passing its original specifications and therefore be condemned as a sub-standard product.

In an effort to eliminate these conditions, the consumer is developing both methods and specifications for durability with the result that the container manufacturer is being forced to use a multitude of different methods for testing his ware. This condition has been brought about mainly by the fact that the literature is lacking in specific information regarding methods for testing this type of glass. The consumer, knowing very little about the properties of glass and the various types of glass, has turned to the literature and adopted tests that were devised primarily for special glasses such as ampoules or chemical ware. In other cases original methods have been developed by the consumer; many of which when analyzed from the glass viewpoint are either valueless or else so complicated that the final results are meaningless. The real solubility problem, as far as the container manufacturer is concerned, is not how to make the container more durable but is the development of a single standard durability test that will meet the needs of both consumer and manufacturer and eliminate the necessity of so many different methods of testing.

The testing of pharmaceutical containers for durability presents a quite different problem than the testing of glasses such as ampoules, window glass or chemical ware. The containers are subjected to an extremely varied chemical attack under conditions of temperature and time that are impossible to control or to even hypothesize. Factors such as the glass composition, the condition of the inner glass surface and the size and shape of the container all have a definite influence on the fitness of the container for its desired use. It can be readily seen therefore that no one durability test can be devised that will answer for all pharmaceuticals.

The only solution to the problem can be nothing more than a compromise and involves the adoption of a standard test incorporating all of the features that are of importance to the consumer. A test that will successfully meet these conditions must embody the following features: 1. A universal solvent such as water must be used as the attacking medium. 2. The temperature of the test must be such that the resulting reaction products are sufficient in quantity to be measured with both speed and accuracy. 3. The bottle itself must be tested as it is the resistance of the inner surface that is the property that must be measured. 4. The test must not be complicated, and both special and costly apparatus must be eliminated. 5. The figures obtained (regardless of the method of expression) must be such that they will allow the consumer to determine both the constancy of each shipment of glass and the relationship between the actual effect of his products on the glass during storage and the measured durability.

There may be found in the recent literature at least three examples of tests employing these principles. The Society of Glass Technology[1] has proposed a tentative test for four-ounce medicine bottles. In this test the bottles are filled with distilled water and heated in a specially designed water boiler to a temperature of 100° C. for five hours. The solution is titrated and the results calculated to milligrams of Na_2O extracted. E. Rexer[2] proposes a test in which the bottle is filled with distilled water and heated in a water bath for three hours at a temperature of 100° C. The solution is titrated and the acid required per each 100 sq. cm. of the glass surface used as a measure of the durability. F. C. Flint[3] has proposed a test in which the bottles are filled with water and autoclaved at 35 lbs. pressure for six hours after which the contents are titrated.

There is no doubt that from a scientific viewpoint criticism may be made of each of these tests or of any other durability test that may be developed. However, the early adoption by the container manufacturer of a standard durability test for this type of glass ware, which will employ the salient features of the above tests will create a common meeting ground for both the consumer and the manufacturer and will do much to prevent the chaotic condition that may be created if the problem is neglected. As conditions now stand, each container and pharmaceutical manufacturer has his own method of testing durability and as a recent editorial on the subject has expressed it: "they don't speak each other's language."

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[1] Soc. Glass Tech., 15, 58, 52, 1931.
[2] Keram Rundschau, 38, 387 et. seq., 1930.
[3] Bull. of Amer. Cer. Soc. 12, 296-299, 1933.

VENETIAN GLASS WITH U. S. MATERIALS

The Italian Government has brought a complete Venetian glass factory to the World's Fair. At the extreme left may be seen Roman Zanetti, whose ancestors have been glass artisans for more than five centuries. These glass workers are using their own tools and materials brought over to this country; but they have been experimenting with American sands and chemicals. Some of these have been found superior to their own and have enabled them to produce colors entirely new to them.

MEASUREMENTS OF THE OPTICAL CONSTANTS OF GLASS

By H. W. LEE

THE optician values glass chiefly for its property of bending light rays. If a ray of light falls obliquely on a plane surface of glass it will be bent away from the surface or towards the normal, and in 1621 Snell, a Dutchman, found that there was a simple relationship between the angles made by a ray with the before and after refraction (called the angles of incidence and refraction respectively and denoted by i and j); viz, that the ratio of their sines is constant for a given material. This constant is called the index of refraction (and generally denoted by n). So

$$n = \frac{\sin i}{\sin j}$$

Ten years later Newton discovered that a beam of sunlight after passing through a prism became colored. His experiments showed that sunlight consists of a number of constituents of different colors, each of which is refracted to a different extent by the glass. He found the following series of colors in the order of their refrangibility; red, orange, yellow, green, blue, and violet. So when refractive index is spoken of, the color for which it is measured must be stated. The color fixed on by the glass makers (following the practice initiated by Prof. Abbe in 1884 at the Schott Glass Works of Germany) has been that given by a flame burning a sodium salt, such as soda. This is known as the D ray. The difference of refraction for two colors is called the dispersion and it has been found (since Newton's time, for the fact eluded his observation) that the dispersion is not the same for all glasses, so that the colors for which dispersion is to be specified must also be standardized. Again it was Abbe who initiated the system in use. The colors he chose are the deep red given out by burning potassium salts (such as potash), called the A ray; the red, blue-green and deep blue constituents of the light obtained by passing a high voltage current of electricity through hydrogen gas at a very low pressure (less than 1/1000th of an atmosphere). These last are known as the C, F and G rays respectively. Abbe also suggested that the quantity $(n_d - 1)/(n_f - n_c)$ which is denoted by V, should be cataloged, as giving a measure of the inverse of the dispersive power. It is, moreover, a number used by the optician in his calculations. (n_d, n_c, n_f denote the refractive indices for the D, C, F rays respectively.)

A new system has recently been adopted by the Parsons Glass Company, England, and the Jena Glasswerke, Germany, in which light given out by an electrical discharge in helium gas, and that of the familiar mercury vapor lamp are used; these are convenient light sources, obtainable commercially now though not in Abbe's time. The system is also more convenient to the optician. The helium tube gives a bright red component (called the b ray), and a yellow component very close to the old sodium light (d ray); while the mercury vapor lamp gives a very much wanted green component (e), a deep blue close to the hydrogen blue (g), and a deep violet (h) which is particularly useful in view of the importance of ultra violet light in photography. It is well known that the sensation of light arises from vibrations and that the different colors are due to vibrations of different frequency. The frequencies of the various colors we have been considering are proportional to the numbers in the annexed table:

			Frequency	
Source	*Designation*	*Old System*	*New System*	*Color*
Potassium	A	1361		
Helium	b		1415	red
Hydrogen	C	1524		
Sodium	D	1697		
Helium	d		1702	yellow
Mercury	e		1831	green
Hydrogen	F	2057		green-blue
Mercury	g		2294	
Hydrogen	G	2304		blue
Mercury	h		2471	violet

At present the two systems are used together, but in all probability when the new system has been assimilated by opticians the old will die out.

Before the Abbe system was accepted, glass manufacturers cataloged only the specific gravity of their

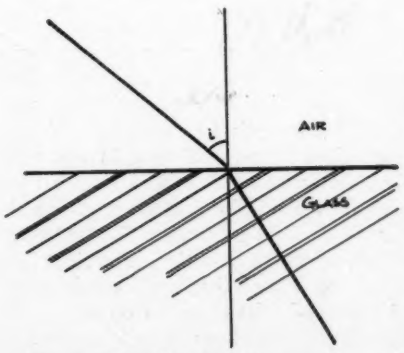


Fig. 1. Refraction at a plane surface.

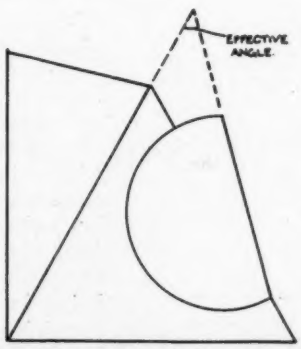


Fig. 2. Wenham's variable angle prism.

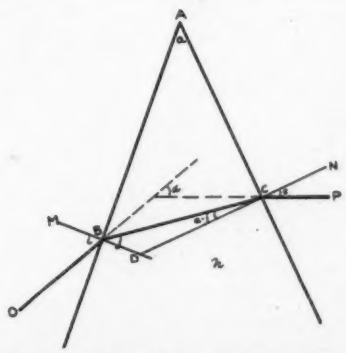


Fig. 3. Refraction through a prism.

glass. With the limited number of glasses then known, this was sufficient to fix roughly the optical properties; if anyone wanted exact measurements of refractive index he had to prepare his own specimen and measure it on a spectrometer, a matter rather for the laboratory than for the manufacturer in those days. The dispersive power was measured for the extreme limits of the visible spectrum (n_1 and n_2) and the refractive index taken as the mean of these: i.e., $\frac{1}{2}(n_1+n_2)=n$. The dispersive power was taken as $(n_1-n_2)/n$. As the extreme limits of the spectrum varied with different individuals, the procedure was not very satisfactory.

THE English optician, Wenham (c. 1860) devised an ingenious method of comparing the dispersive powers of glasses with that of standard crown glass before such data were supplied by the makers. A prism of the standard glass was made with a cylindrical cavity into which a cylinder of the same glass fitted, and could be rotated so as to vary the angle between the outer faces of the prism. The specimen to be measured was made in the form of a prism and attached to the variable prism with oil. The angle was then varied till the dispersion of the specimen was equal, and in the opposite direction, to that of the standard. By measuring the angles the ratio of the two dispersions was determined.

Measurement of Refractive Index and Dispersion. Snell's equation gives us the necessary means for measuring the refractive index. In practice of course the glass block has two faces and if these are parallel to one another the ray emerges parallel to its original direction; therefore a block with non-parallel faces must be used, i.e. a prism.

Fig. 3 shows the case of refraction through a prism ABC of angle a. The incident ray OB meets the prism at B; DBM is the normal, so that MBO is the angle of incidence (i.). The ray is refracted along BC in the prism, so that CBD is the angle of refraction (j). At the second face DBN is the normal, and from geometry the angle of incidence BCD=a—j. The ray is refracted out into air as CP with angle of emergence NCP (e). It can be shown that

$$n^2 \sin^2 a=\sin^2 i+\sin^2 e+2 \sin i.\sin e.\cos a \qquad \text{(i)}$$

The ray OB has suffered deviation in its passage through the prism, the angle of deviation being that betwen OB and CP (d in the figure) and

$$d=i—e—a \qquad \text{(ii)}$$

Equation (i) looks rather awkward but in practice two special cases only are considered.

(a) Measurements are made in the position where i=e, so that d=2i—a, and the equation reduces to

$$n \sin \tfrac{1}{2}a=\sin i$$

or

$$n=\frac{\sin \tfrac{1}{2}(d—a)}{\sin \tfrac{1}{2}a} \qquad \text{(iii)}$$

which gives n directly from a measurement of the angle of the prism and of the deviation of the ray; both of these angles are measured on a spectrometer, which is shown in diagramatic form in Fig. 3. C is a collimator consisting of a tube having at one end a corrected lens and at the other a fine slit at the focus of the lens and with its length perpendicular to the plane of refraction; i.e., the plane of the paper. The slit is illuminated and the light is converted into a parallel beam by the lens. This beam takes the place of the ray we have hitherto postulated, which is of course only mathematical abstraction. The rays of the beams are all parallel to one another and will therefore all suffer the same deviation; so our equations will apply to the whole beam, which, after refraction through the prism, passes into the telescope T where an image of the slit will be focussed by the objective and viewed by an observer looking through the eyepiece E. A hair line or cross wire is provided in the focal plane of the objective and serves for locating the image. The prism P is supported on a table which can rotate about a central vertical axis, about which also the collimator and telescope (or at least the telescope) can rotate, and their positions can be read off on the graduated circle C. The angle between the directions of the collimator and telescope is the deviation. Fig. 5 shows the appearance of the slit image as set on the hair (b) or cross wire (a).

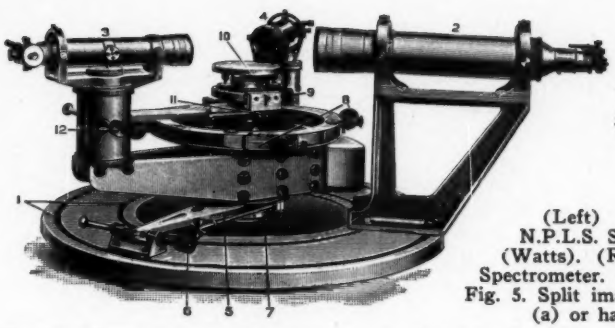
It can be shown that when the angles of incidence and emergence are equal the deviation is a minimum. To find this position the prism table is given a rotation and the telescope moved to follow the image until the position where the deviation is a minimum is found; a slight rotation of the prism now in either direction will increase the deviation; this gives a simple method of finding this position.

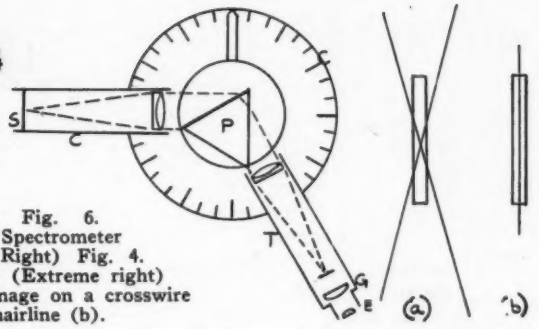
It remains to find a. This is done by reflecting the light beam from the collimator from each of the faces AB, AC in turn. The angle the telescope turns through when the reflected images of the slit are successively placed on the cross wires is twice the angle of the prism.

In accurate refractometry it is found best to make the angle a=60° and to polish the third side to make two further angles of 60°. This has two advantages: in the first place as the sum of the angles of a triangle is 180°, we have a simple check on the measurements of the angles; secondly, even if the angles differ individually from 60°, Dr. Glazebrook found that the mean value of the deviation measured from each angle in turn is the same as if each angle was exactly 60°. Therefore it is not necessary to spend time in making the angles with excessive accuracy.

Spectroscopes of the type described are used for the most accurate refractometry. The instrument illustrated was made by E. R. Watts, Ltd., London, for the National Physical Laboratory. The graduated circle is 15 inches in diameter and reads directly to half a second. It is possible to measure refractive indices to the fifth figure after the decimal point. (See Proceedings of the Optical Convention, 1926, p. 937).

THE construction of a 60° prism involves the accurate working of three optical flats and requires a considerable amount of glass. Abbe devised a somewhat more economical and rapid form requiring only a 30° prism with two optical flats. The telescope T (fig. 7) has a small window in the side through which light from a lamp S can enter. A small prism R illuminates a slit lying above but in the same plane as the cross wires G, situated in the focal plane of the telescope objective. The light is thus rendered parallel and falls on the front face of the prism. It is refracted there and falls normally on the rear face. Here it is again reflected back to enter the telescope again; but through the lower half of the objective which images





(Left) Fig. 6. N.P.L.S. Spectrometer (Watts). (Right) Fig. 4. Spectrometer. (Extreme right) Fig. 5. Split image on a crosswire (a) or hairline (b).

the slit on the cross wires, where it is observed by the eyepiece E. The actual refraction is equivalent to that of a 60° prism in minimum deviation and, moreover the setting is automatic. This is the principle of autocollimation. Not only is the expenditure in preparing the prism cut down but the instrument is economical in dispensing with a separate collimator, and the automatic minimum deviation makes it quick in operation. Parsons Optical Glass Company, England, recently adopted this form for the refractometry of their glasses. Their instrument, shown in Fig. 8, was made by Ross, Ltd., London; it has an 18 inch circle which reads directly to 1 second. (Proceedings of the Optical Convention, 1926, p. 925).

(b) The second position employed in practice is that in which the incident light grazes the face of the prism; i.e. i=90°. This was originally suggested by Wollaston in 1802 and was later adopted by Pulfrich in his refractometer. In this instrument a fixed prism is used and the specimen DAB fig. 9, having a right angle at A, is placed upon it. Light incident on the interface in the direction OAB is refracted along BC if the refractive index of the prism is greater than that of the specimen, and emerges as CP. The formula in this case is

$$n_2^2.\sin^2 a = n_1^2 + \sin^2 e + 2n_1.\sin e.\cos a \qquad \text{(iv)}$$

where n_2 is the refractive index of the fixed prism and n_1 that of the specimen. A ray in the direction O_1A will be reflected at the interface and not enter the field of observation; a ray in the direction O_2A will be refracted to emerge at a larger angle than e. Thus the grazing ray corresponds to a limiting value of e. The beam emerging from the prism is focussed in a telescope with a sharp edge corresponding to the above value of e. A graticule in the eyepiece is in the form of a strip of silver with a gap in one edge. This edge is placed against the edge of the beam, the gap facilitating the setting. The position of the telescope is read off on a divided circle.

If the prism has an angle of 90° (as it was in the original Pulfrich instrument), equation (iv) reduces to the simple form

$$n_1^2 = n_2^2 - \sin^2 e$$

If n_2 is known for each color for which we desire to

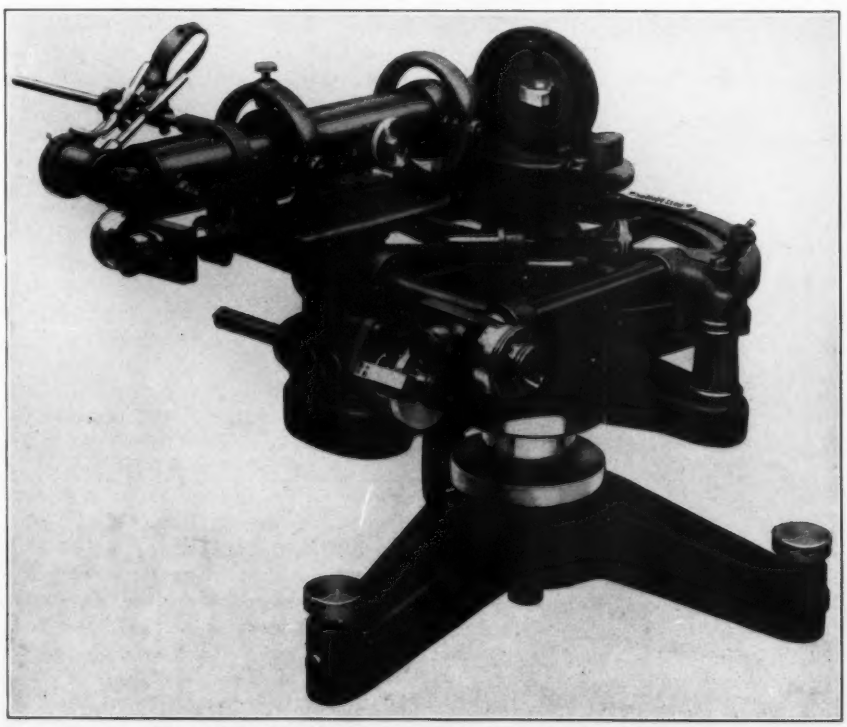


Fig. 8. Parson's Glass Company's Autocollimator (Ross).

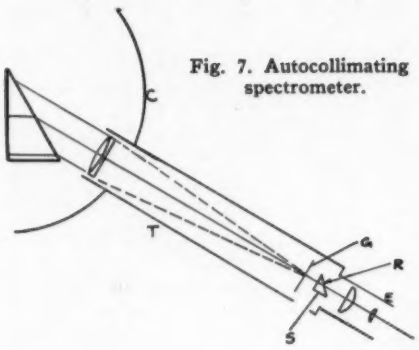
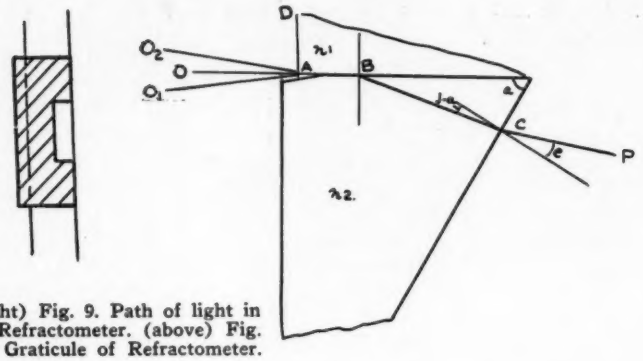
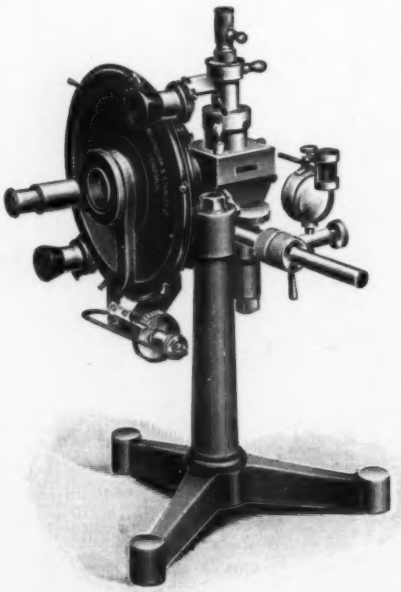


Fig. 7. Autocollimating spectrometer.



(Right) Fig. 9. Path of light in the Refractometer. (above) Fig. 10. Graticule of Refractometer.

measure n_1 we have only to measure e. This information can be obtained by measuring e for a known glass (or quartz) occupying the position of the specimen; otherwise it is necessary to depend on values supplied by the maker and obtained by him from a specimen of the same melting on the spectrometer. This is not a very satisfactory proceeding as the refractive indices of different pieces from the same melting may differ appreciably. It is preferable therefore to make a=60°, so that the refractive index of the actual prism can be measured and the instrument checked at any time without the necessity for secondary standards. The instrument (fig. 11) made by Bellingham & Stanley, Ltd., London, is of this type. The circle is seven inches in diameter and reads to one minute, so that refractive indices can be measured to one unit in the fourth decimal place. Differences of index for different parts of the spectrum can be measured to ten times this accuracy by means of a micrometer screw for moving the telescope, having a drum reading to 1/10th of a minute. By means of this the telescope is set successively on the colored lines and the differences read off on the drum. Thus dispersions are found to one or two units in the fifth decimal place. The makers supply a set of tables facilitating the working out of the refractive indices so that it is not necessary to work out the formula (iv). The accuracy thus falls far short of that obtainable with the best spectrometers, but the rapidity of operation and the speed and economy with which the specimen can be prepared (only one small optical flat polished on a thin sample, with a roughly polished window at right angles to it) make this instrument eminently suitable for routine measurements by the optician and the glass maker, though the spectrometer will of course always be required by the glass maker for basic measurements. The specimen having been prepared for the refractometer, it is applied to the prism with a spot of liquid which has a greater index of refraction (monobromonapthaline suffices for 99 per cent of the work) and the graticule set on the edge of the band when (ɛay) sodium light is used, and the position of the telescope on the graduated circle. A prism is then swung out of the light path, cutting off the sodium light and allowing light from a hydrogen tube to fall on the specimen. The telescope is moved from one to the other and the drum of the micrometer read at each position, the difference giving the angular dispersion for the C and F rays. Reference to the tables gives the refractive index n_d and the dispersion $n_f - n_c$, whence $V=(n_d-1)/(n_f-n_c)$ can be found. These measurements usually suffice to indicate the glass in the catalogue, from which spectrometer readings may be taken.



(By Bellingham & Stanley, London).
Fig. 11. Pulfrich Refractometer.

GLASS DIVISION OF AMERICAN CERAMIC SOCIETY PLANS PROGRAM FOR FALL MEETING

Members of the Glass Division program committee met July 14 at the summer home of Dr. J. T. Littleton on Keuka Lake to discuss their plans for their fall meeting. Among those in attendance were Dr. George W. Morey of the Geophysical Laboratory, Washington, D. C., James A. Bailey of Hamburg, N. Y., chairman of the 1935 Glass Division, W. C. Taylor and Dr. John C. Hostetter of the Corning Glass Works, Corning, N. Y., Francis Flint of Hazel-Atlas Glass Co., Washington, Pa., and U. E. Bowes of Owens-Illinois Glass Co., Toledo, O.

THE TRADITION OF THE ELDERS

By FRANK W. PRESTON

THE ancient and honorable occupation of glass making goeth back so far that tradition speaketh not to the contrary. It antedates all history. And in all ages its devotees have considered themselves a superior race of craftsmen, not a part of the common herd. Until recently they that worked optical glass into lenses in London, went to work in top hats; but in all ages the glass worker has been wont to high hat the envious multitude.

In six or eight thousand years a great deal of empirical knowledge can be assembled, and unlimited experiments can be tried. Most of the experiments would naturally turn out failures; that is, they would make the glass or glassware worse rather than better, for in glass as in morals, strait is the gate and narrow the way that leadeth to perfection, and wide the gate and broad the way that leadeth to destruction.

Of all the materials on this earth, few of themselves will form a glass, and of these few only one—sand— is of general utility. Of all the other materials on the earth, only two or three will reduce the fluxing temperature of sand to a manageable heat. To all intents and purposes only the oxides of sodium, potassium, and lead are of any use, and these do not occur native. The ashes of land plants are the only available sources of potash in most localities, though sand is somewhat generally plentiful.

The resulting mass is only glassy, as a rule, if the proportion of sand to soda or woodashes lies within narrow limits and then the product is soluble in water and of poor weathering and mechanical properties. A third ingredient must be added, and again the choice is very limited. Only limestone, of one sort or another, is of much use. Once more, the proportions of sand, lime and soda must lie within rather narrow limits for the temperatures available to primitive industry, or even modern industries.

Yet "primitive" man mapped out this much of the art thousands of years before the Geophysical Laboratory began to discourse of Ternary Eutectics, and in fact long before chemists of any sort established the composition of Sand, Limestone, or Woodashes.

Working with impure materials, of unknown composition, the best way to obtain consistent results is to obtain the materials consistently from the same source and prepare them under identical conditions. This is the way the natives of Central Africa make Iron for their assegais, and it works as long as no-one in the party dreams of his wife. In the same way, glass making is successful if no changes are made and the ancient traditions are observed.

The difficulties and dangers of making even slight changes have frequently been brought home to the writer, in this age of supposed enlightenment and scientific knowledge, and with apparently competent technical advice and preliminary experiment.

California is mostly sand, yet Californian glass plants have had to use imported European sand till recently. There is no difficulty, so far as can be seen, in analyzing the California sand chemically and mineralogically, and nothing impossible with the analysis when found. Yet as soon as the stuff is put in the tanks, the glass acts differently and awkwardly.

Alumina should be as easily obtained from kaolin as from feldspar, according to its chemistry, but in practice it is much less easy.

Every method of introducing chromium into glass is troublesome in one way or another, and a change from one method to another is not simply a matter of stoichiometrical proportions.

A simple change from high calcium to dolomitic lime can play Hamlet. The effects are complicated, for though the quarternary eutectic may be much lower than the ternary eutectic, and therefore, by the rules of the Geophysical, the mixture may be ideal for glass making, there may be a substantial increase in the viscosity that needs changes along the line in the production shops.

Some of these things we now understand, and some we don't. The conservative course is to stick to something well tried. This is true of glass compositions, but still more true, in many cases of machinery. There are few more complicated machines than some glass working ones, and few more massive than some others. There is much at stake in a change. Therefore let us be careful before we load a tank, containing 200 tons of glass, with a new ingredient, or redesign a plate glass polishing machine, or start the development of a new feeder.

On the technical side, the present state of the industry is undoubtedly high-brow; that is, it has been stuffed with more scientific information than it has scientific judgment to assimilate.

The polariscope is a good instance. The industry does not understand the polariscope, but it uses it—and in consequence, for the most part, misuses it. Like fire, the polariscope is a good servant, but a bad master. The kind of annealing that is required of a bottle is the kind that will give the maximum of service from the bottle, not the kind that will make the bottle show the least color in the polariscope. A tradition has been established that the polariscope must be obeyed, and the obedience is often wooden.

THROUGHOUT the testing of bottle ware, at least, empiricism is rampant. In the hydrostatic test, there is observed the internal water pressure needed to break the bottle, but no calculation is ever made of the stress developed in the glass, to see if the glass is really normal. The test is commonly regarded as a search for weak seams or other thin spots, but a minimum of use is made of the information.

In the thermal shock test, similarly, the stresses developed by the test are never calculated, and what is reasonable for a bottle to stand is never figured out. Nor is the normal distribution of thermal strength over a large number of bottles known in any plant. The test is a purely empirical one, and is commonly made at the empirical shock difference of 76°F, though no-one seems to know how this mystic figure originated.

A thermal shock of 76°F on a normal bottle glass should not develop a stress exceeding about 3800 lb./sq. in. in the glass. This seems a rather low figure to break good glassware, yet a small percentage of bottles does normally break on this test, especially if the bottles be well annealed. What is the reason for this? Apparently the tradition of making the test is followed very generally, yet no one enquires scientifically into its significance.

Everyone knows that a cracked bottle is not strong. Plate glass men are very careful to eliminate "vents" of the smallest kind from the edges of large plates before they start to carry them around, for "vents" may "open up"—that is, the crack may extend and break the plate in two. A bruise on a bottle is a crack or series of cracks, or "vents", even if small. Are they dangerous like the vents in plate glass? A few of us know a partial answer to the question, but probably but few.

When bottles come out of the lehr they are inspected. Usually an inspector holds four in his hands at once. He bumps them together, producing little bruises. This is the tradition. Is it wise? If not, how unwise is it? Some say the bottle is going to get bruised sooner or later, and it might as well be soon as later. They even go so far as to bruise the bottles deliberately before hydraulic testing, so as to get the strength of a "worn" bottle. But bottles just leaving the lehr are more tender than bottles that have cooled off and perhaps gathered a film on their surface. Is it fair and proper to bruise them while tender? Would the bottle perhaps be stronger if handled "with kid gloves" for the first hour or so of its existence? In any case, who knows the strength of old bottles, bottles that have been really worn?

In the plate glass business, grinding and polishing remain essentially traditional arts. Fine grinding or smoothing is done at one plant by sand, at another by garnet and at another by emery. Their comparative merits are uncertain. The reason they are thus used is that each plant started out with a particular abrasive and it sticks to it as part of its culture-complex. It is a tradition.

Rouge for polishing is a great mystery. In fact, polishing altogether is a mystery. But rouges from different sources are undoubtedly different, and the difference has never been explained. Whenever there is trouble in a plant, the plant reverts to its historic source of rouge.

LET it be understood that I am not blaming plant managers for this: I should probably do the same thing myself. But it is curious that so little is yet known about the fundamental requirements, when some of the largest and richest corporations in the country have so much at stake in them. Reliance on tradition for technical information, and on selling policies for profits has been the rule with the plate glass companies. The engineering progress in these firms has been remarkable, though possibly no greater, and certainly no more refined, than in the bulb-blowing or bottle-making business. But their contributions to the technology of glass have been few, and their participation in the spread of scientific information has tended more and more towards zero. It is a tradition with them that the less they disclose, the more of an edge they have on the business. Yet the Ford Motor Company which is the least secretive in this respect, has been in most respects the pioneer of them all.

The wire glass business has been the poor relative of the plate glass industry. It could be practiced in plants involving much less capital outlay, and using much more moderate labor forces. It has held its own almost entirely on the basis of the original inventions. It contributes next to nothing to scientific knowledge of glass or of its own problems in glass, though it has at least one or two men of outstanding technical ability, and definite technical progress could be made. It seems however, in most plants, to follow solely on traditional lines. Its only progress tends to be a copying of certain improvements made by the plate glass industry, which in turn, as we have said previously, seems to improve only to the extent of copying the automobile industry.

THE inertia of the glass industry necessarily is the inertia of its personnel. Few of the progressive elements of the population are attracted to the industry as it stands. A few good engineers have been attracted to the mechanical problems of plate glass making, with remarkable results. Three or four chemists of ability have somehow drifted into the industry and produced equally remarkable results (which have, however, not always been fully utilized). But both chemistry and engineering are becoming more and more branches of physics in its broad sense, and the industry is deplorably short of men with any sound grasp of physics.

The chemists that have done outstanding work in glass are not, as a rule, the analytical chemists, but those who think in terms of physics. For glass after all is not a chemical substance, but a physical state of certain chemical substances.

Glass probably first attracted attention by its transparency; and it is still sold mainly because it is transparent. And transparency is a physical property, not a chemical one. In some cases one desires a certain translucency or diffusion, and this again is a physical problem, now being put on a scientific basis by a handful of workers. Or we desire color, and color is a physical phenomenon, and a most difficult one to define.

Glass is valued for its mechanical hardness, which is a physical condition; for its refractoriness or infusibility, which is a physical property, also. It is damned for its brittleness, which is certainly no chemical problem. One firm has become famous largely as the result of exploiting a glass with a low thermal expansion, and though chemists produced the glass in the first instance, they were interested solely in a physical property.

Annealing is a physical problem and most plants are all at sea on annealing problems because they have no grasp of the physics of either annealing or polariscopes.

Glassware breaks and hush money is paid out in substantial sums, either by order of the courts or by settlement out of court, because neither chemists nor factory managers understand the fundamental physics of breakage.

It would seem that the greatest step forward the glass industry could take would be the attracting to its staffs of adequate numbers of able physicists. At present these men are going into the electrical industries and the other younger industries where the Inertia of Tradition is less overwhelming.

CHEMICAL DURABILITY OF CONTAINERS

By A. K. LYLE
Hazel Atlas Glass Co.

THE satisfactory service of glass demonstrated by its increasing popularity marks it as an ideal container material for foods and related products. Glass jars have been used for home packing of fruits and vegetables to the exclusion of other types of containers. The pleasing appearance and the easy adaptability of glass to individual design have made it much favored for commercial food packing so that many products formerly marketed in bulk are now commonly sold in glass containers. The packing of cheese, nuts, coffee, spices and many other products in glass has become quite common. For liquids, such as beverages, milk, extracts and vinegar, glass is the logical container. To this list may be added the familiar products of home canning, vegetables, fruits and jellies.

Because such a variety of food products is packed in glass there has been some questions asked concerning the effect foods have upon glass and the extent to which glass is effected by them. The answers to these questions have been found in investigations of the chemical resistance of glass and in studies involving foods in contact with glass.

The repeated use of jars in home canning gives a good answer to the durability question. Barring breakage, the normal life of fruit jars is apparently unlimited. Jars twenty years old are just as serviceable as ones newly purchased, and inquiry has developed the fact that jars of this age are not uncommon. Milk and beverage bottles, as well as fruit jars, are filled and refilled many times. Such containers may represent fifteen or twenty sterilizations in boiling water or as many washings in some alkaline cleaner. This treatment is in addition to their normal time of contact with fruit or vegetable juices which may total several years. Since glass stands up under these conditions, it is certain that it is not harmed by contact with foods.

However, the commercial packing of a large variety of foods by methods not applicable to home use, has called for laboratory investigations concerning the effect of glass on foods. Attempts to improve flavor and appearance and to preserve the vitamin content of foods have been considered in relation to the container.

Glass containers are usually made from simple sand-soda-lime glass, possibly containing small amounts of other materials such as alumina or boron. The proportions of these raw materials can be varied but very little so that the analysis of glasses from different sources will show only slight variations in composition. When liquids such as water or water solutions are held in contact with the glass, small amounts of the alkali, silica, and lime are extracted. The amount extracted depends upon the nature of the test solution, the time and temperature of contact, and the composition of the glass, as well as the area of glass exposed. Fruit and vegetable juices have pH values of less than seven, and since most soda lime glasses possess good acid resistance, very little glass is dissolved during continued storage.

A number of investigations have been conducted in order to determine possible effects on foods caused by alkali derived from the glass. The change of acidity which takes place during the sterilization of foods was studied by A. Radin[1]. Standard two per cent peptone solutions ranging in pH values from 4.0 to 8.0 were sterilized in glass and tin containers at an autoclave pres-

WINNING ARCHITECTURAL DESIGN USES MORE GLASS

Geoffrey Noel Lawford of New York designed this house and won first prize in the architectural competition sponsored jointly by the publication "Pencil Points" and the Plate Glass Industry. Bigger and better windows and mirrors was the principal aim of the competition. Here are the window areas of the principal rooms in the house. Living room, 36 per cent glass; breakfast room, 76 per cent; kitchen, 28.3 per cent; master bedroom, 25.1 per cent; guest bedroom, 28.7 per cent; daughter's bedroom, 49 per cent; son's bedroom, 41 per cent; servant's bedroom, 30 per cent.

sure of fifteen pounds for thirty minutes. The pH value was lowered in all cases, and the change was almost identical for glass and tin. The same procedure using several vegetable and fruit juices indicated only slight changes in the pH value. Since both the glass and tin containers acted alike, changes in pH values must be due to reactions within the solutions or juices during sterilization. J. R. Esty[2] arrived at practically the same conclusion while working with "soft" and "hard" glasses in connection with the determination of sterilization temperatures. He found that "hard" glass gave up acid and lowered the pH value, while "soft" glass which would be comparable to container glass caused no change. C. S. Purcell[3] determined the pH values of vanilla extract during a six months contact with glass and found it to be constant. It was estimated that 0.23 milligrams of alkali was extracted from an ounce bottle whereas one hundred and fifty times this amount would be necessary to neutralize an ounce of extract. H. A. Barnby and W. H. Eddy[4] proved by feeding tests that the vitamin C content of tomato juice was not lowered by storage in glass containers. W. H. Lockwood[5] reported satisfactory storage of glass-packed foods at temperatures averaging well above 80°F.

The practical service tests as illustrated by the repeated use of fruit jars and beverage bottles as well as the evidence presented by the various researches on food in contact with glass demonstrate quite definitely that the slight solubility of glass in fruit and vegetable juices presents no great problem in chemical durability. It is important to note that in these investigations no reference has been made to the glass composition so that it is reasonable to assume that glass of average composition is satisfactory for food containers.

However, a number of accelerated tests for the determination of chemical durability have been proposed which for many problems are quite valuable. Nearly all of these tests are much more severe than actual service requirements. In order to get significant figures with sufficient accuracy two methods in general have been employed: autoclave and powder. Autoclave tests accelerate the solution of glass by means of increased pressures and temperatures. Temperatures from 125°C to 135°C for five or six hours are customary. This method has the advantage of testing the same surface that is actually used. Powder methods simply increase the area of glass exposed to the test solution by crushing the glass to a specified size and thus obtain sufficient attack at room or slightly elevated temperatures.

These accelerated tests are of little value and are certainly not necessary for successful food packing. Such tests may be used by the glass manufacturers to good advantage for controlling quality or for determining the results of composition changes, but the problem of chemical durability for glass food-containers does not call for any specific standard test.

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[1] A. Radin, Biology & Public Health Thesis. *Mass. Inst. Tech.* (1922). [2] J. R. Esty, *Jour of Infectious Diseases* 29, 29-39 (1921). [3] C. S. Purcell, *The Glass Packer* 11, 438 (1932). [4] H. A. Barnby & W. H. Eddy, *The Glass Packer* 11, 33 (1932). [5] W. H. Lockwood, *The Glass Container* 10, 16 (1931).

THE GLASS INDUSTRY FROM THE AIR

The progress of the Glass Industry in the last generation was largely an engineering and machine development: the next generation will presumably see great advances in the technology of glass. At Alfred, N. Y., a year ago there was established the first chair of glass technology in this country, Dr. Scholes being the first incumbent. The photograph shows the village of Alfred as seen from the air. The New York State College of Ceramics, with the Glass Technology Department are housed in buildings near the center of the picture beyond the conspicuous short cross road.

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SOME NEW MEANS OF PRODUCING EXTREMELY HIGH TEMPERATURES

By WILLI M. COHN
Alameda, Calif.

Abstract. Investigations at very high temperatures require the solution of a number of interesting problems. Some modern means of obtaining extremely high temperatures in the laboratory are: Use of an electric arc in connection with two hollow mirrors; tungsten and molybdenum furnaces for work in oxidizing or reducing atmospheres or in the vacuum; and gas fired zirconium oxide furnaces. Electron bombardment of solids is the most satisfactory method for vacuum work. High temperature investigations under very pure conditions have been carried out recently using the radiant energy of the sun. These investigations may be carried out in any atmosphere or in the vacuum. Both electron bombardment and the sun furnace make it possible to obtain temperatures limited only by the evaporation of the sample. Some other means are mentioned for obtaining very high temperatures for very short intervals.

AT ROOM temperature, an almost infinite number of compounds is known in the solid, liquid and gaseous states. If we increase the temperature, the thermal motion of the molecules will become stronger and the velocity of reaction will increase considerably, resulting in an almost instantaneous formation of equilibria. Next, a region is obtained in which, besides elements, only very few compounds exist. The gas phase is predominant. With further increase of temperature, molecules will be dissociated and atoms will be ionized by removing the electron shells. The limits of high temperature research work have been extended more and more in recent years. We are not able, however, to obtain such extreme temperatures at which, theoretically, only free electrons exist and nuclei of the atoms. It will be of interest to review some new means of producing very high temperatures. Only such methods will be discussed which give high temperatures for long periods.

Ordinary refractories cannot be used above 1400 or 1500°C. We must build our furnaces from high melting metals or compounds; such as carbides, oxides, nitrides and borides. Table I contains melting points of elements and compounds for high temperature work. All these substances will withstand the high temperatures only if heated under certain conditions. We distinguish furnaces operated in a reducing or a neutral atmosphere, or in the vacuum, and those operated in an oxidizing atmosphere. Special care should be taken to use pure substances for this type of work, as very small amounts of impurities may decrease their refractoriness considerably.

(*a*) *Furnaces operated in a reducing or neutral atmosphere, or in the vacuum.* Carbon and electric arc furnaces have been used extensively both in the laboratory and in industry. A new type of arc furnace has been developed recently: An electric arc is placed in the focus of a hollow mirror and the sample in the focus of a second mirror, see figure 1. This will result in heating the sample under purer conditions than is possible in most arc furnaces.

Several types of tungsten and molybdenum furnaces have been developed in recent years since we have learned to make sheets and tubes from these metals. The electric current passes through a metal tube and heats it directly in the "short-circuited" furnaces. A spiral of tungsten or molybdenum wire or ribbon is used in different types of furnaces, see figure 2. (Tungsten will melt at 3400, and molybdenum at 2620°C.) The difficulty is to find a refractory material which will withstand such high temperatures, especially in a reducing or neutral atmosphere. Tungsten furnaces may also be built for working in an oxidizing atmosphere: I have been using special zirconium oxide tubes as furnace walls, and more recently, artificial corundum has been used for the same purpose. These materials will remain gastight up to 2000 and 1800°C respectively thereby permitting maintenance of an oxidizing atmosphere inside the furnace and keeping the heating elements in a reducing or neutral atmosphere.

One can avoid the problem of refractory furnace walls entirely by suspending the tungsten or molybdenum spiral in the vacuum. The maximum temperatures obtainable now are 2800 and 2300°C respectively as both elements will become too soft at higher temperatures.

A heating method entirely different from the ones discussed above is the heating of solid bodies by means of electron bombardment (or cathode ray bombardment). Figure 3 shows an arrangement which I used recently: A tungsten wire is heated in the vacuum to 1800°C. Electrons will be emitted from the wire. The wire is used then as a cathode and the container to be heated as an anode. The electrons from the wire will strike the container and will heat it to as high a temperature as desired. The anode may be a tube which contains the sample to be investigated, a crucible or the sample itself. The only temperature limit of this heating

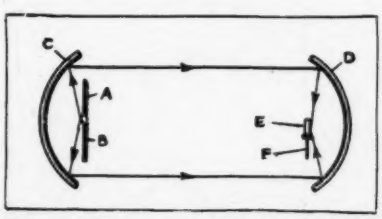

Fig. 1. Carbon arc reflection furnace, a, b= electrodes, c, d=reflectors, e=sample, f= holder.

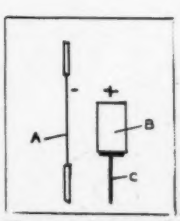

Fig. 3. Electron bombardment furnace, a=incandescent wire (cathode), b= sample or container (anode), c=holder.

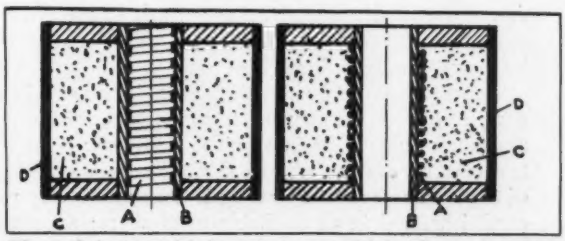

Fig. 2. Spiral type resistor furnaces with heating coils inside and outside of the furnace tubes respectively, a=heating spiral, b=refractory furnace tube, c=heat insulating material, d=aluminum shell.

method is given by the melting and evaporating of the container and the sample. Instead of a wire, a pointed cold cathode may be used. I believe that this is the most satisfactory heating method for vacuum work developed so far.

(*b*) *Furnaces operated in an oxidizing atmosphere.* Several types of gas fired furnaces are available now using the oxides of zirconium, magnesium, or thorium as wall materials. Figure 4 shows a furnace into which gas or a gas-liquid mixture is introduced tangentially resulting in a rotation of the flame and giving temperatures up to 2500°C.

From the high melting metals, iridium may be used up to 2100°C in an oxidizing atmosphere, or iridium-

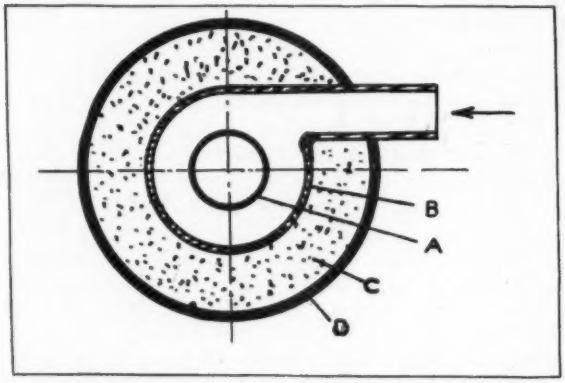

Fig. 4. Gas furnace a=zirconium oxide tube for sample b=zirconium oxide walls c=heat insulation material d=aluminum shell.

rhodium alloys up to 2050°C. One serious disadvantage of iridium furnaces is seen in the formation of an iridium oxide below 1200°C which will evaporate and contaminate all platinum-platinum/rhodium thermocouples etc. in the laboratory.

All the high temperature heating units mentioned above and also the well-known high frequency furnaces are operated by means of gas or electricity. A different supply of energy has been used recently in obtaining very high temperatures; namely, *the heat from the sun.* The surface temperature of the sun is believed to be about 6000°C. The principle used successfully in the sun furnace built in the Zeiss Works in Jena is this: A large plane mirror of about 100 inch diameter follows the motion of the sun and reflects the radiation from the sun to a large hollow search light mirror of 100 inch diameter. (That is the same diameter as that of the famous Mount Wilson astronomical mirror.) The entire energy is then concentrated in the small focal spot of the hollow mirror which has a diameter of only 8 millimeters. Here is placed the substance to be investigated, see figure 5.

Temperatures obtained with the sun furnace will melt every solid material known. I have melted, for instance, zirconium and magnesium oxides into clear glasses at temperatures of more than 3000°C. The main advantages of the sun furnace are: Heating is done under very pure conditions, and in an oxidizing atmosphere; no electric or magnetic fields are present which may disturb the reactions or spectra to be studied; a very short time is required for obtaining the highest temperatures, more

Table I. Melting points in degrees centigrade for some elements and compounds used in high temperature work.

Element		*Oxide*	*Carbide*	*Nitride*	*Boride*
W	3400°C	1550°C	2870°C	....	2920°C
Mo	2620	....	2690	(Mo_2C) ..	....
C	3630	....	....	....	....
Ta	3025	....	3840	3090°C	....
Os	2700	....	....	....	....
Ir	2350	....	....	....	....
B	2250	....	....	3000	....
Nb	1950	2050	3500	2050	....
Ti	1800	....	3170	2950	....
Pt	1771	....	....	....	....
V	1715	2240	2830	2050	....
Th	1842	3050	2773	....	....
Zr	1857	2690	3710	2980	3000
Fe	1530	....	....	....	....
Re	3170	....	....	....	....
Ni	1450	....	....	....	....
Rh	1965	....	....	....	....
Si	....	1710	2540	1900	....
Al	....	2050	....	2200	....
Cr	....	2020	....	....	....
Ca	....	2585	2300	....	....
Mg	....	2800	....	....	....
Be	....	2570	....	2200	....
Hf	....	....	3900	3300	3060

than 3500°C being reached, for instance, in about 30 seconds. By placing a quartz glass bulb over the sample it is possible to use the sun furnace for work in a reducing or neutral atmosphere, or in the vacuum.

Some other methods of obtaining very high temperatures are the use of one or several explosives, discharging large condensers through a very thin wire, burning of aluminum, firing a bullet into a closed cylinder, etc. All these methods will give high temperatures only for a very short interval, and therefore have not been discussed in this paper.

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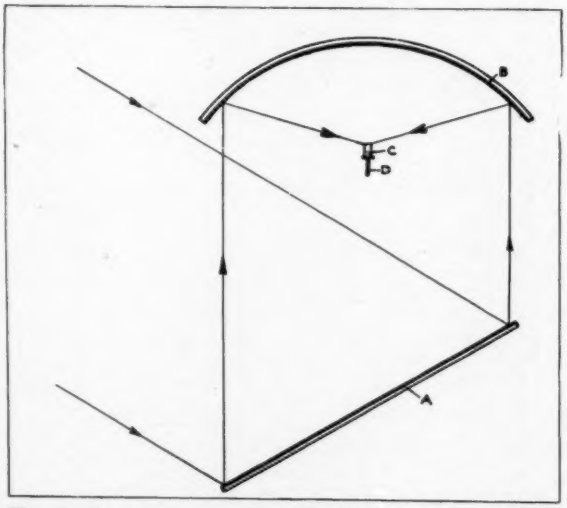


Fig. 5. Sun furnace a=100 inch plane mirror b=100 inch hollow mirror c=sample d=holder.

A NEW TYPE OF LEHR IN OPERATION AT MACBETH-EVANS GLASS COMPANY

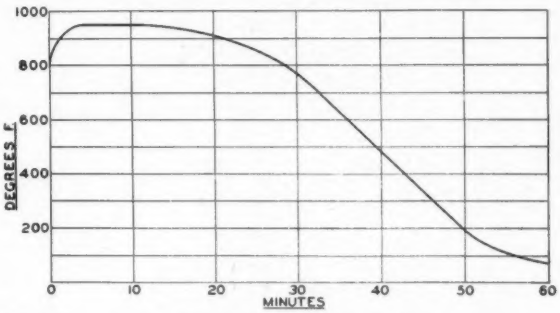
A NEW type of direct-fired lehr has recently been placed in operation by the Macbeth-Evans Glass Company at their Elwood, Indiana plant. This plant manufactures lamp chimneys, lantern globes, silvered reflectors and jugs of high quality.

The new lehr is of the continuous wire mesh belt type and is 6′ wide inside width of conveyor by 75′ long. The lehr in general is unique in that it has no muffles, stacks or exhaust fans. The heating is accomplished largely by convection rather than by radiation. The fuel used is natural gas.

The firing system consists of a number of units located on each side of the lehr and extending for approximately a third of the length of the lehr. For decorating lehrs, the firing system is extended over a greater length. One valve control is employed which uses the energy in the air to inspirate the gas and to maintain accurate proportions over a wide range of capacity. This feature insures a non-reducing atmosphere in the lehr and therefore gives a beautiful surface and lustre to the ware, even without the use of a muffle. Each firing unit is provided with a separate hand control so that most any time temperature cycle can be obtained. This feature makes it practical to anneal or decorate in the same lehr.

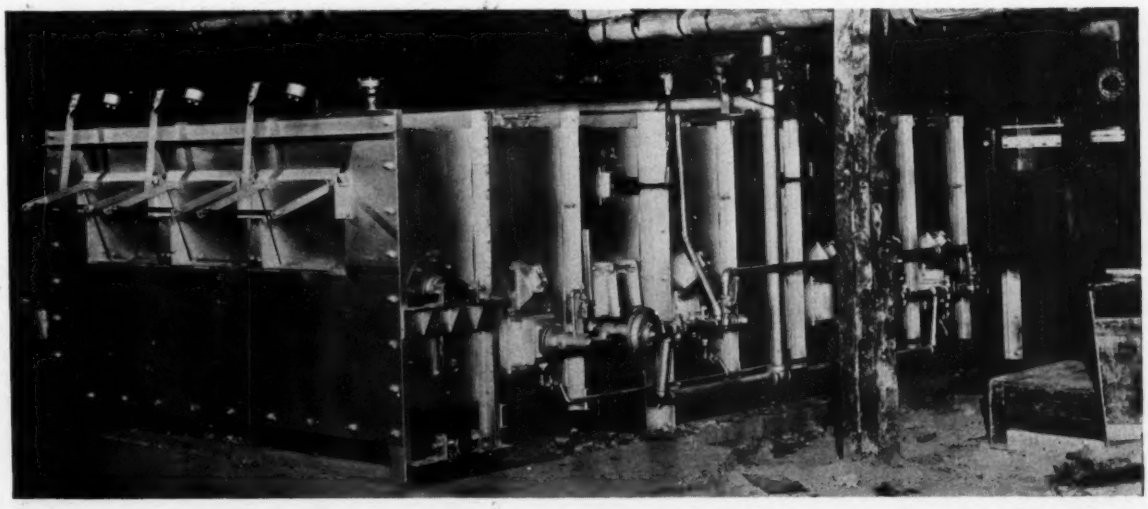
The time temperature cycle, when obtained by hand adjustment, is maintained by automatic control on a master valve operating a supply of air for combustion. A two point high and low rate of firing is the system used. In addition to the automatic control equipment, a recording pyrometer is used connected to a large number of thermocouples located throughout the length of the lehr at both top and bottom of the lehr. The accompanying time temperature curve is found best suited for the particular product and is easily maintained.

In much the same manner as the fuel is introduced for heating, air is introduced at regular intervals from the end of the firing zone to the discharge end of the lehr. The air is admitted through nozzles which cools the gases in the lehr and, therefore, controls the rate of cooling corresponding to the amount of air added. This system not only speeds up the cooling, but keeps a pressure in the lehr throughout its length. This system, therefore, eliminates the need for a stack or exhaust fan.

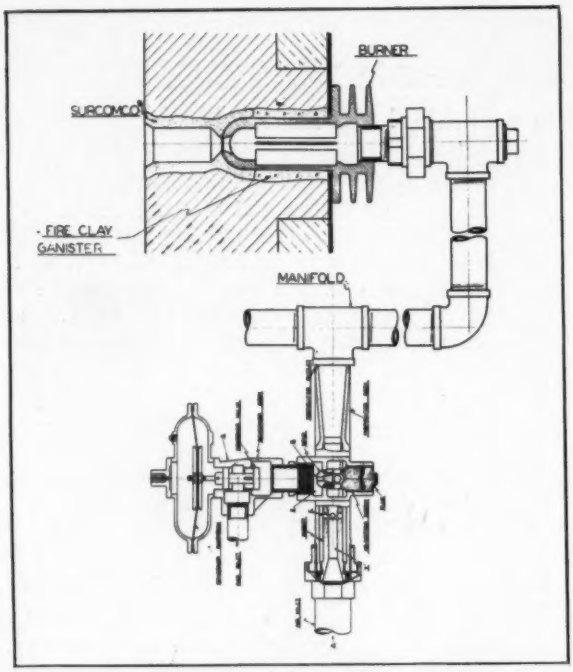


Time Temperature Curve for 6 ft. lehr, 75 feet long, operating at conveyor speed of 15 feet per minute.

Flues leading from the top of the lehr to the firing unit allows the products of combustion from the firing system to inspirate and to recirculate these gases from the lehr back into the stream of hot gases. By this means, the gases around the ware are kept in constant circulation which insures uniform heat distribution in any cross section of the lehr. This method also increases the volume of product in circulation, insures a pressure in the lehr, and reduces the amount of fuel required. The same method of recirculation is employed in the



Charge end Surface Combustion wire mesh belt type lehr installed at Macbeth-Evans Glass Company, Elwood, Indiana. This view shows the firing system, S. C. low pressure, automatic proportioning, one valve control, inspirator-tunnel burner equipment with pilots.



Left. Diagram showing operating principle of firing system used in Surface Combustion lehr for Macbeth-Evans Glass Company.

cooling zone as is used for heating. In the cooling zone the cooling air passing through the nozzle furnishes the energy for recirculation. This same uniform distribution of heat in any cross section is, therefore, insured throughout the length of the lehr.

The above features of heating by radiation, uniform heat distribution over a 72″ wide conveyor by recirculation and increased rate of cooling by using pressure air, gives this lehr an unusually rapid rate of good annealing. Even while annealing glass of 5/16″ to ⅜″ thick, the speed of the conveyor is operated at approximately 15″ per minute. The fuel rate is unusually low for this size and capacity of lehr.

Because of the absence of muffles, the lehr can be safely brought up to temperature in a few hours and, therefore, insures low maintenance and also added reduction in fuel by reduced holding rates over week-ends.

The extreme flexibility in operation, the ease at which the time temperature cycle can be changed, the low operating costs and the quality of annealing, even on ware with a wide range of thickness, makes this lehr an outstanding installation.

NEW TYPE WINDOW

A revolutionary type of double glazed window, known as Thermopane, which substantially reduces heat loss through windows and prevents frosting in cold weather, is being acquired by the Libbey-Owens-Ford Glass Company through a newly organized subsidiary, The Thermopane Company, it was announced by John D. Biggers, president of the parent company.

The product consists of two panes of glass so fitted to each window sash that it provides a dehydrated air space between and reduces the flow of heat and cold, Mr. Biggers said. The device, which has been applied successfully in solving problems of air conditioning, is expected to have a widespread effect in the construction of windows in new homes and buildings.

Building engineers also have found that the Thermopane principle, besides preventing frost formation, eliminates condensation on the glass of windows, unless the inside humidity is excessively high.

In making the announcement, Mr. Biggers said that the Libbey-Owens-Ford Glass Company has completed arrangements to acquire the business, patent rights, and good will of Charles D. Haven of Milwaukee, who, for the past four years has been producing the new type of window. Mr. Haven will be president and operating head of The Thermopane Company, which will continue operations in Milwaukee. As the business grows, it is contemplated that other plants will be located in Toledo and elsewhere, Mr. Biggers said.

Mr. Biggers explained that the expanding demand for air conditioning and the trend towards insulation in new building are factors responsible for this latest acquisition by the Libbey-Owens-Ford Glass Company.

"Our company has been greatly interested in this new development in glazing since practical air conditioning first became an established fact," Mr. Biggers continued. "Our engineers have made exhaustive studies of various methods of reducing heat losses through windows and have concluded that the Thermopane process is the most practical means as yet developed for reducing these losses."

Tests conducted by engineers showed that the new principle saves about 50 per cent of the usual heat loss through windows. The engineers also predicted that the double glazing idea will be used widely in the refrigeration field, particularly in refrigerator display cases now so generally employed in grocery and meat markets.

CORNING GLASS WORKS PLANS A NEW 200-INCH TELESCOPE MIRROR

Plans for casting a new 200-inch telescope mirror, a twin to the one poured last March, have been announced by the Corning Glass Works. The decision to pour a second large mirror was made because it will take about as much work to complete the first mirror as to make an entirely new one.

It will be remembered that during the pouring of the first reflector, parts of the mold came loose and there was considerable speculation at the time as to whether the huge disc would prove a success. While it was subsequently found that no important defects existed, still considerable work was necessary before the disc could be made usable. An entirely new mirror will therefore be poured and the first disc kept in reserve.

In casting the second mirror, a new alloy will be used for the anchor rods that is more heat and corrosion resistant. It is expected that this will prevent parts of the mold from breaking loose, either from melting or from rust. This is the only important change to be made.

The Department of Commerce reports that the far-famed glass industry of Czechoslovakia is now undergoing one of the most serious periods of depression experienced for years, 40 of the 120 glass works normally in operation having shut down and a majority of the remainder working part time.

THE OWENS-ILLINOIS EXHIBIT AT A CENTURY OF PROGRESS

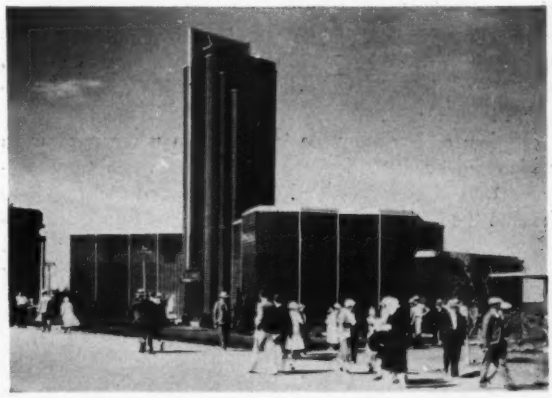
Glassware made by the Egyptians 2000 B. C., as well as some of the finest examples of the glassware of all ages, selected from the famed collection of the Toledo Museum of Art, are among the interesting new attractions being shown by Owen-Illinois Glass Company at the Century of Progress.

The Owens exhibit is housed in the Glass Block Building, erected by the company as a demonstration of the use of glass block as a practical building material possessing many architectural advantages, and of itself one of the outstanding attractions of the Fair.

Housed within the Glass Block Building is an animated miniature of a complete glass factory in actual operation, which not only acquaints the general public with the processes involved but no doubt provides a familiar atmosphere for the many members of the industry who visit the Fair. Legends synchronized with electrical signals and connected with the mechanism, clearly depict the whole process of bottle making in an understandable manner.

The glassware exhibit includes specimens of every period of glass making, from its earliest beginning down to that of the present day. Among the colorful container displays are the new vacuum packed coffee jars, tamper-proof bottles for lubricating oils, and preserve jars for fruits and vegetables.

Of great interest to the artistically inclined is a complete line of Libbey stemware, as well as many beautiful specimens of the Steuben craftsmen. Here one can see, too, the famous etched punch bowl which won for Libbey Glass Company a gold medal in the World's Columbian Exposition in 1893. Illustrated below is a miniature display of glass-block structures, residences, industrial plants, stores, dairies and filling stations.



TEMPERATURE MEASUREMENT OF FLOWING GASES

IN THE glass plant it is very often necessary, especially when data on furnace operation is being collected, to determine the true temperature of gases flowing through the furnace system. For example it is sometimes necessary to determine the temperature of the waste gas, preheated producer gas or air passing through the regenerators or recuperators of a furnace. In most cases when this type of data is being secured a thermocouple is placed in the gas stream and the indicated temperature assumed to be the true temperature of the gas. Consideration of the following factors will show that this assumption is erroneous. In nearly all high temperature systems there is usually a substantial temperature difference between the flowing gas and it surroundings. As the junction of the thermocouple will receive heat by both radiation and conduction from the gas and by radiation from the surroundings, the temperature of the couple will always lie between the temperatures of the surroundings and of the gas itself. The thermocouple reading therefore represents an equilibrium condition, as the flow of heat by conduction between the gas and the thermocouple becomes equal to the flow of heat by radiation between the thermocouple and the surroundings.

If then a thermocouple is placed in a regenerator in which the brick work is colder than the gas (measurement of waste gas temperature) the couple will radiate heat to the brickwork and will indicate a temperature intermediate between the gas and the brickwork and will therefore show a lower gas temperature than is actually the case.

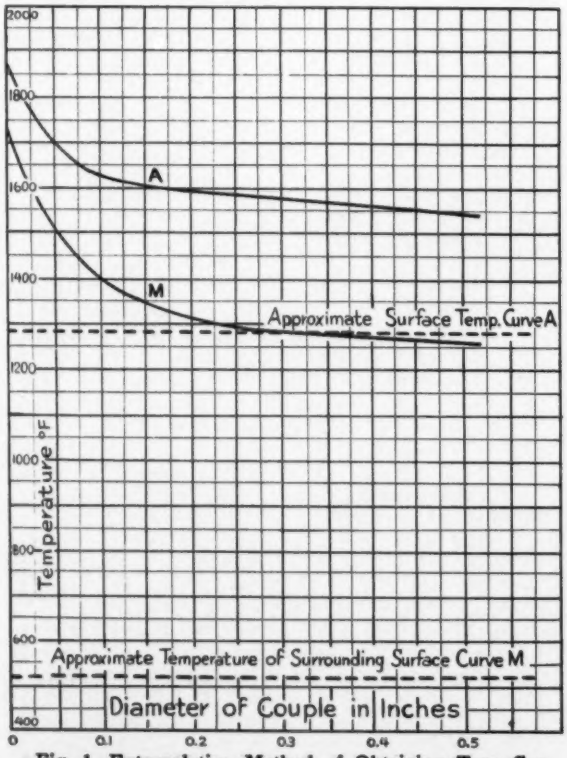


Fig. 1. Extrapolation Method of Obtaining True Gas Temperature (Kreisinger and Barkley).

TABLE 1

	Position A °F	Position M °F
Couple diameter, 0.008 inch	1780	1670
Couple diameter, 0.450 inch	1550	1270
Difference in temperatures	230	40

TABLE 2

Location of Couples	Temperature (Degs. F.) Ordinary Couple 0.5 mm.	Suction couple	Temperature Difference (Degs. F.)	Remarks
Air Reversing Valve....	716	725	9	Waste Gas
" " "	761	779	18	" "
" " "	779	806	27	" "
" " "	905	941	36	" "
Stack temperature.....	923	950	27	" "
" "	968	1004	36	" "
" "	1004	1031	27	" "
Regenerators	1409	1454	45	" "
"	1562	1625	63	" "
"	1346	1175	−171	Air
"	1256	1058	−198	"

On the other hand if the brickwork is hotter than the gas (measurement of preheated air) the couple will be hotter than the gas but not as hot as the walls and the indicated gas temperature will be in error in a plus direction.

To secure true gas temperatures it is therefore necessary to eliminate or reduce to a negligible quantity these radiations effects. Several methods for accomplishing this have been proposed, for example it has been found that a bright silver cover on the thermocouple will greatly reduce the effect of radiation. In practice however, this method is not satisfactory due to the screens preventing free circulation of the gas around the couple and the fact that the screens tarnish in corrosive gases or at high temperatures. Another method that has been advocated is the use of couples of very small diameter. The rate of conduction of heat becomes greater and the radiation loss less when the wire diameter is decreased. Kreisinger and Barkley (1) placed a large and a small thermocouple side by side in a boiler setting and compared their readings. Table 1. They then assumed that a couple of infinitely small diameter would read the true gas temperature. By using several thermocouples of varying diameter in a cluster and then plotting the indicated temperatures, they were able to determine the true gas temperature by extrapolating the curve to zero diameter. This is illustrated in Fig. 1.

Another method, developed by Haslam & Chappell (2), that has come in to use in the last few years and which is both simple and efficient is by the use of suction to promote heat exchange between the couple and the gas. As shown in Fig. 2 a small thermocouple is surrounded by a quartz or porcelain tube. This is inserted in the gas stream whose temperature is to be measured and a rapid stream of gas is drawn out through the tube by suction. As the high velocity increases the rate of conduction, both the inner surface of the tube and the thermocouple tip approach the true gas temperature. As the tip is surrounded by a surface which is close to the true gas temperature the radiation effect becomes neg-

(*Concluded on page* 155, *col.* 2)

CORNELIUS O. WATNEY

CORNELIUS O. WATNEY, vice-president and treasurer of Ogden-Watney Publishers, Inc., publishers of THE GLASS PACKER and THE GLASS INDUSTRY, died on July 7th at Greensboro, Vt. Mr. Watney was taking a much needed vacation with his family in the Green Mountains. While swimming one afternoon, he called suddenly for help, and though friends quickly responded and brought him to the shore, he never regained consciousness. Interment was at Portland, Oregon, July 14.

When death overtook Mr. Watney he had reached his thirty-fourth year, but in his brief career he had probably lived life more fully than many of four score and ten. By giving to life, he got from life. By nature generous, frank and loyal, these qualities were engraved upon his personality and all men loved him. Few in the glass industry had a wider circle of friends. These knew him as a true gentleman.

Mr. Watney was born in Seattle, Washington, August 11, 1900. He attended the University of Washington, but financial difficulties interrupted his college education. For two years he was employed by the Standard Oil Company of California, and then was able to resume his studies at the Oregon State College. Here he managed several college publications with unprecedented financial success. After graduation he was employed by the *Oregon Farmer* and later by Miller Freeman of Seattle.

In 1928 he and another organized the Ogden-Watney Publishers, Inc., which gave the glass container industry its first independent business journal, THE GLASS PACKER. Two years later THE GLASS PACKER absorbed THE GLASS CONTAINER. As recently as March of this year, Mr. Watney and his partner acquired THE GLASS INDUSTRY.

In his own community, Madison, N. J., Mr. Watney was known as one of the leaders in social and civic life. He was a member of the governing board of the Methodist Church and a director of the Y. M. C. A. Active in Masonic work, he was a member of Madison Lodge 93, A. F. & A. M., Overlook Chapter 44, and was a Knight Templar. He had been urged to take political office, but the pressure of business and other interests compelled him to decline. Mr. Watney is survived by his wife, Dorothy Munsell, and two children, Joanne and William.

THOMAS F. HART PASSES

THOMAS F. HART, founder of the Hart Glass Manufacturing Co., Dunkirk, Ind., and a pioneer in the glass industry of the Middle West, died at his home in Dallas, Texas, on July 6. Mr. Hart was 83 years old on Feb. 5, his last birthday. He had been taken to the hospital about six weeks previously, and had undergone two major operations during that time. Burial took place in Muncie, Ind.

Mr. Hart came to Muncie in 1888 from Bellaire, Ohio, and with J. M. Maring founded the Maring-Hart Glass Co., in Boyceton, Ind. This concern later merged with the American Window Glass Co., of Pittsburgh.

Almost to the end of his life Mr. Hart took an active interest in the affairs of the glass company which he founded at Dunkirk. He attended the annual meeting of the company last Jan. 11-13, and even while on his death bed at Dallas sent a letter to F. H. May, executive of the company, asking to be informed of conditions there.

TEMPERATURE MEASUREMENT OF FLOWING GASES (Concluded)

ligible. The reading of such a couple is therefore very nearly the true temperature of the gas being measured.

As an illustration of the method of use and the results obtained with a suction type pyrometer the recent work of Parkin and Winks (3) may be quoted. These investigators using both a suction type thermocouple and an ordinary thermocouple obtained a series of measurements of the temperatures of gases at the regenerators, air

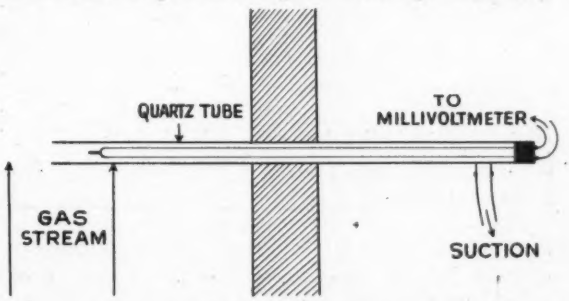


Fig. 2. High velocity thermocouple.

valve, gas valve and at the stack. A few of them shown in Table 2. These results show that there is considerable difference in the temperatures obtained by the two thermocouples. Where large temperature differences exist between the brickwork and the gas (see results on preheated air measurements) a corresponding large error will exist if the temperature of the gas is taken in the ordinary manner.

[1] Bur. Mines, Bull., 145, (1918). [2] Ind. Eng. Chem., 17, 4, 402, 1925. [3] J. Soc. Glass Tech., 16, 63, 315, 1932.

EDUCATION AND RESEARCH IN GLASS TECHNOLOGY

By Professor W.E.S. TURNER

IN RESPONDING to the invitation of the Editor to contribute an article to The GLASS INDUSTRY, I cannot take any more appropriate subject than that indicated by my title, for The GLASS INDUSTRY has, as one of its chief objects, the dissemination of technical information, based on sound scientific training and knowledge.

The subject indicated by my title is so considerable that it could well occupy a series of articles. It must suffice to sketch the main lines of progress in the provision of facilities for instruction and research.

Prior to the war, courses of instruction in glass technology were carried on in Austria (Bohemia) at Haida, and also in Germany as, for example, at Zwiesel in Bavaria. The work done was of a very useful character but neither of these institutions had a standing beyond that of the trade school, and teaching and research of the character of that now available was not attempted. Both institutions still carry on admirable work and, at Zwiesel, Dr. Springer has carried on for a number of years very useful research on subjects relating to glass melting processes. In England also a course in the elements of glassmaking was conducted long before the war, at the Wordsley Technical School, near Stourbridge, Mr. Frederick Carder, now well-known and honored in America, being the enthusiastic leader.

The modern development, involving placing at the service of the glass industry all the resources of science, began in 1915 with the founding of the Department of Glass Technology at the University of Sheffield, England. This development was the outcome of war needs and of the realization that the glass industry was a field which had been hitherto almost entirely neglected by scientific workers. It began its work in the belief that as a Department of applied science it must have an essential and intimate relation to the glass industry and all its doings. The courses established in the first year, therefore, consisted of classes in a number of centers where the glass industry was carried on; and if the students learned much from their teachers, as they aver they did, the teachers undoubtedly learned much of the practice of glassmaking from their students. Within a year or two, a complete system of University courses of instruction in glass technology came into being. When it was possible for the Department to begin research, the very first research was based on one of the numerous practical problems on which a solution was asked. This plan of making the researches directly applicable to the immediate needs of the industry was pursued over quite a number of years and only in more recent times have more fundamental researches, which look to development of the industry in the future, been embarked on, in addition to those of a more immediately applicable character. From 1917 to date, some 300 researches and reports on research have been published.

Since 1915 the importance of glass technology as a distinct science has been more and more widely recognized and at the present time nearly a score of higher institutions provide courses for instruction or facilities for research in glass technology, or both. The accompanying table is a summary of the position, and comments on various countries.

In addition to the Department of Glass Technology, two other bodies contributed during the period from approximately 1915-25, towards research work in glass technology in England. The first of these was the National Physical Laboratory at which, under the direction of Dr. W. Rosenhain, in the Department of Metallurgy, a number of researches relating to glass and refractory materials for the glass industry were carried out.

The other body was the Glass Research Association set up in 1919 in London and active until the end of 1924, or more strictly, June 1925. This organization had a very substantial sum of money put at its disposal by the Government and substantial contributions were made from the industry. The Director of the Association, Mr. R. L. Frink, was well known in America. A considerable volume of work and quite a number of published researches, especially bearing on glass manufacture were the outcome of the activities of this body.

Since 1925 all resources in England have been concentrated in the Department of Glass Technology, and during a period when funds available are limited there is very much to be said for concentration of effort at one or two strong centers, rather than spreading them over a substantially larger number.

Confining our attention still for the moment to Europe, Germany in 1922-23, recognizing both how much progress was being made in England and also how desirable it was to organize her own substantial resources of scientific knowledge in connection with glass, brought three special activities into being for the service of the glass industry. One of them

Country	Town	Institution	Teaching & Research: Glass Technology	Teaching & Research: Ceramics or other subjects with Glass	Research only
England	Sheffield	University	Yes	...	...
Germany	Karlsruhe	Technische Hochschule	...	Yes	...
	Hannover	Technische Hochschule		Yes	...
	Berlin	Technische Hochschule	Yes	...	...
	Aachen	Technische Hochschule	...	Yes	...
	Berlin	Kaiser-Wilhelm Institut	...	...	Yes
America	Alfred	Alfred University	Yes	Yes	...
	Urbana	University of Illinois	...	Yes	...
	Pittsburgh	University of Pittsburgh	Yes	...	...
	Columbus	Ohio State University	...	Yes	...
	Washington	Geophysical Laboratory	...	...	Yes
	Washington	Bureau of Standards	...	...	Yes
	State College	Penn State College	...	Yes	...
Russia	Moscow	State Scientific Glass Institute	Yes	...	...
	Leningrad	State Scientific Glass Institute	Yes	...	...
Czecho-Slovakia	Hradec Kralove	Glasforschungs-institut	...	...	Yes
Denmark	Copenhagen	Technical High School	...	Yes	...
China	Shanghai	National Laboratory for Chemical Research	...	...	Yes

was a Department of Glass Technology at the Technische Hochschule, Karlsruhe, which Professor E. Zschimmer, who had spent many years as leader of research at the works of Schott und Genoesen, Jena, was called on to preside over. The courses originally established were later somewhat modified and the department became known as the Glas-und Tonforschungs Laboratorium. In addition to its teaching work, a good deal of valuable research has been published during the past dozen years. Professor A. Dietzel, who has recently succeeded Professor Zschimmer, is maintaining the high standard set.

The work at Hannover, where glass is combined with ceramics, is presided over by Professor G. Keppeler, whose reputation, both by reason of his editing of Dralle's "Die Glasfabrikation" and by the considerable body of researches which have been coming from his Department, is everywhere known.

The laboratory at the Technische Hochschule, Berlin, is presided over by Dr. F. Eckert assisted by Dr. F. H. Zschacke. A considerable number of researches of a practical character have been published from this laboratory.

At the Technische Hochschule, Aachen, Professor H. Salmang directs the Institut für Gesteinshüttenkunde; but although his interests are not confined to glass, the work of instruction and Professor Salmang's own researches have had a strong glass bias. He has, for example, made noteworthy contributions to the subject of gases dissolved in glass—a subject on which Dr. E. W. Washburn, when at the University of Illinois, was a modern pioneer.

Then there is the Kaiser Wilhelm Institut für Silikatforschung founded in 1926 and presided over by Professor W. Eitel. Its field of work is similar to that of the Geophysical Laboratory, Washington, but by virtue of the support which it receives from the glass and ceramic industries it has a direct obligation to carry on researches having a direct bearing on glass and ceramics. Each year a number of research communications on glass find their way from this institution into the literature and each year in November the institution holds a meeting for the delivery and discussion of papers dealing with a selection of the researches in progress.

I have not included in the list of institutions in the table any reference to Professor Gustav Tammann's Department at the University of Göttingen. There is no Department of Glass Technology, nor is there any systematic teaching of glass technology. In the main also Professor Tammann's results have been based on the use of organic glasses. But he has made noteworthy contributions to our knowledge of the processes of crystallization on the one hand and glass formation on the other, and has made a special contribution to the phenomena which take place round about the transformation point which occurs in glasses.

ALTHOUGH I am concerned mainly in this article with teaching and research in educational institutions or public research institutes, I cannot leave the subject of Germany's contribution without referring to the outstanding research contributions from one or two of the industrial organizations. The classical researches by Otto Schott and his colleagues at Jena, not only established an honorable place for that works for all time in the history of glassmaking, but also provided the first systematic basis for a science of glass. After a considerable period from the beginning of this century onwards, in which the contributions from Jena were comparatively few, the laboratories have in the last six years again been contributing a very useful quota to the subject of glass and of glass refractory materials.

The most outstanding of the contributions from industrial establishments, however, are those from the Osram G.m.b.H., which began under the leadership of Professor G. Gehlhoff. The researches, which began to see publication in 1925 have covered a very wide field in glass technology and have been of the utmost value. It is also worthy of note that a number of students have carried on work in the laboratories of this company to obtain material for a thesis for their Doctorates.

IN America pride of place, so far as public institutions are concerned, must go to the Geophysical Laboratory, Washington. From 1906 onwards, under Dr. Arthur Day and his colleagues, data were being accumulated which, although intended for quite other purposes, were destined a decade or so later to be of value in beginning the solution of fundamental glass technological problems; and when America entered the war in 1917 the demand for optical glass resulted in a group of scientific workers of the Geophysical Laboratory placing themselves at the disposal of the country to set about, in two or three different factories, the successful manufacture of this necessary optical glass. Thus, the workers of the Geophysical Laboratory were brought directly into touch with the glass industry and this led to the undertaking of a number of researches having a direct bearing on the industry. The Geophysical Laboratory still carries on work of fundamental use for glass technology.

The call of Dr. E. Washburn to the Professorship and Head of the Department of Ceramic Engineering in the University of Illinois in 1916 may be said to have introduced glass technology into University teaching circles in America; for although the Department of Ceramic Engineering at Illinois has always had to deal with a considerable variety of ceramic subjects, Dr. Washburn soon showed that he had a special leaning towards the problems of glass. His work on gases dissolved in glass and the viscosities of the soda-lime-silica glasses will give him a permanent place in the history of glass technology. If the original interests of Prof. C. W. Parmalee, his successor, lay in the field of general ceramics, he has shown by the encouragement he has given to glass research over a period of years, that he is alive to its special importance.

At Pittsburgh, although Professor of Chemistry, Professor Alexander Silverman has never lost his first love, namely, glass; and although the activities there have never resulted in a department for glass, a course of instruction on the subject is given to senior students and research work is frequently undertaken.

At Ohio State University I believe I am correct in saying that the presence of Dr. S. R. Scholes in Columbus made it possible to run a course of lectures on glass technology. So far as I know, this course has never blossomed into anything more substantial.

The movement which led to the establishment last year at Alfred University of a Department of Glass Technology is one greatly to be commended. Glass technology certainly has relations to scientific studies in some branches of ceramics, but it has always been the writer's view that an important subject like glass technology should have individual attention if it is to make real and rapid progress, and that related subjects should be considered in the light of the assistance and service they can give to glass technology. For this reason the establishment of a Department of Glass Technology at Alfred University under Dr. S. R. Scholes marks for America a new and promising development.

THE Bureau of Standards has also been making important contributions to our knowledge of glass technology in the last decade. In the first place the Department of Commerce has an actual optical glass manufacturing plant, making glass for the American navy and in association with that work has carried out a number of measurements of fundamental properties of glasses. That work still continues.

We also recall the important work published in 1920 by Tool and Valasek and by Peters and Cragoe, which led to the recognition of the special changes which occur in the properties of glasses in that temperature interval which is frequently spoken of as the annealing range. Contributions on the subject of the effect of the thermal treatment of glass have continued to come from Dr. Tool and his colleagues. Dr. Coblentz and his associates have enriched our knowledge of the ultra-violet light transmission of glasses. Dr. Washburn and his colleague Dr. Bunting in the Chemistry Division have also published several papers of considerable interest and we can only deplore the early death of Dr. Washburn which has removed from glass technology an enthusiastic and able worker.

I have not mentioned in the table the name of the Mellon Institute, Pittsburgh, for the simple reason that glass technology is not carried on in any organized way; but everyone knows that from time to time very useful research work has been carried out at the Mellon Institute and that Dr. E. W. Tillotson, who has usually had something to do with guiding such researches.

There are still other institutions in America in which research work on glass is being carried out. They include the Massachusetts Institute of Technology; the Department of Ceramics, Pennsylvania State College; Purdue University; and also Stanford University, California, at the last of which Dr. G. S. Parks in the Department of Chemistry has for several years been carrying on research work dealing with the theory of the vitreous state.

And no reference to research in glass technology in America can possibly be complete without mentioning the Corning Glass Company, whose manufactured products are in a very large measure the new glasses which have been the results of intensive research by a large band of highly skilled scientific workers over a period of a generation. In addition to researches which from time to time it publishes, the Corning Glass Company has also provided considerable sums in support of Research Fellows undertaking glass technological researches at institutions of University rank, and, in general, has exercised a fertilizing influence on progress.

I have but limited space to refer to developments in other countries but first reference must be made to Russia where very great activity is being displayed in modernizing methods of glass manufacture and in providing a personnel for carrying it on, trained in the latest knowledge. The literary output in Russian glass circles is very substantial; not only research output, but also textbooks of various types, large and small. A number of small books, for example, have appeared, such as that of S. Rodin, written in a simple way for the benefit of operatives in the Fourcault glass industry. Whilst some of the published research has been associated with the search for cheap minerals for glassmaking and has brought us no real advance of knowledge, there has been a substantial contribution on the other hand of new work which is deserving of being better known than it is.

In Czechoslovakia a new research institute was set up about two years ago at Hradec Kralove under the direction of Dr. V. Ctyroky. The economic crisis has delayed the development of this laboratory due to shortage of funds but it is good to see the foundation of a research institution in this country which has so large a stake in the glass industry.

Denmark cannot be said to be a glassmaking country. There are but two or three works; but it may be mentioned that Professor A. H. M. Andreasen has recently equipped new laboratories at the Technical High School, Copenhagen, for research on ceramics and cement and has included provision for work on glass.

In France there is yet lacking any center organized for the purpose of training and research in glass technology, although we do not forget Professor Henri Le Chatelier's Laboratory and the fact that a number of important researches have been published from it, even in recent times.

The situation in Belgium is even less satisfactory. More than ten years ago Monsieur Lefebvre discussed with the writer the possibility of starting a department of glass technology at Charleroi, and other attempts have been made in the last two years to have the problem seriously discussed and a strong center of instruction started, but so far no scheme has come to success.

In Italy Professor A. Mauri has for some years been conducting a school of glass technology in Venice, under an education scheme which provides technical instruction for the minor industries of Italy. There is considerable hope, with the developments now taking place in Italy, that provision for glass technological teaching and research in that country will be made much more adequate.

The latest of ventures in connection with glass technology which have come to my notice is associated with the National Laboratory for Chemical Research, Shanghai, China. During last year I was written to for advice in regard to the possibility of setting up glass research at that centre and later in the year was most interested to receive a communication from Mr. C. F. Lai telling me that he had been appointed to develop that work. Mr. Lai was a student of Professor Silverman in Pittsburgh. We may give him our cordial good wishes for successful work in the new venture.

FOREIGN TECHNICAL PAPERS

TRANSLATION By S. R. SCHOLES

ELECTRICAL GLASS MELTING* (Conclusion)

Heating elements in the form of rods of non-metallic material have recently come on the market in America. These conductors of silicon carbide require no especial protection against oxidation in the normal furnace atmosphere. They carry the trade-names, "Globar", "Silit", and "Quartzit", and come in standard dimensions.

Since these resistors attain the necessary temperatures, they make possible the construction of furnaces for melting glass electrically with indirect resistance-heating. They deserve detailed description.

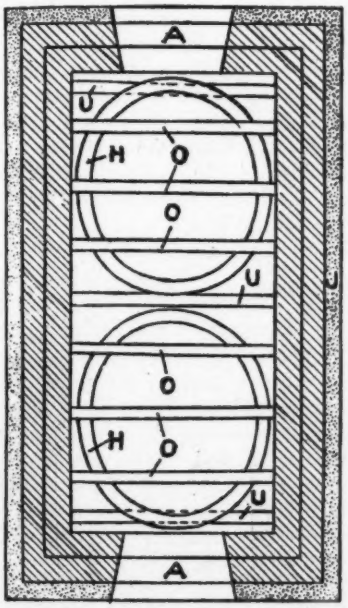
The structure of commercial silicon carbide resistors is not standardized. We may distinguish between those made up of many small silicon carbide crystals solidly bound in a fritted material, and those composed of somewhat larger crystals bedded in a granular body. Besides these, there are resistors with very large crystals, interlocking to form an aggregate.

Silicon carbide (SiC) is an electric furnace product, formed from coke and sand about 2000°C. It is an exceptionally hard material, supplied by the manufacturers in crystals selected according to grain-size.

The heating elements, formed from this material bonded into rods or strips, have uniform diameter throughout. They may be heated to 1420°C. indefinitely, and may be operated for brief periods up to 1650°C., without softening. They possess great strength and a very low coefficient of expansion, together with a high specific resistance, permitting large heat-development in a limited space. They are supplied in various lengths and diameters, according to the current specifications under which they are to be used. Dimensions range from 6 in. to 5 ft. in length, and from 6mm. to 20 mm. diameter. They may be used vertically or horizontally.

The manufacturers† of "Globar" resistors state the resistance of their element at 16 ohms for a rod 1 in. long and 1/16 in. diameter, corresponding to a specific resistance of 1240Ω. From this datum may be calculated, by the usual rules, the resistance of an element of any specified size. The resistance is fairly constant from about 500°C. up, and is some 50 per cent higher at room temperature. As units age in use, they develop higher resistance, which eventually ends their useful life. Voltage-regulation is required, for the control of heating.

The resistors are installed in such a manner that they are easily removed and replaced. The outer ends are sometimes water-cooled, sometimes arranged with pressure-contacts of low-heat conductivity but ample carrying-capacity for the current.



Principle of Electric Pot-Furnace with Silicon Carbide Heating Units. H—Open Pots, A—Work-holes, O—Upper Resistor, U—Lower Resistor, J—Heat-insulation.

The refractories surrounding and supporting the electrodes must be non-conductors (insulators). This condition is of greater importance for furnaces with indirect resistance-heating than for units where the glass itself is the resistor. As already suggested, the refractories in general use in furnace construction begin to be conductors at the high temperatures reached. Materials vary greatly in conductivity. Henry[1] has shown that alundum cement has much greater resistance than fireclay, although the curves for these two materials approach each other closely, as 1500°C. is reached, with resistances of 600 to 800 ohms/cm³. Werner[2] showed the superiority of silica brick over common tank blocks.

Since the refractories are not perfect insulators, a limit is placed upon the voltage that can be used. This may not exceed 500 volts, and for the most part 220 volts or 380 volts are the practical limits.

Resistors in the form of sheets or strips have been found practical for temperatures up to 1400°C.[3] These heating-elements, made largely of silicon carbide, have been proposed for indirect resistance-heating. This offers the outstanding advantage, that no especial precautions need to be taken against discoloration of the glass. The heat is transmitted entirely by radiation. A furnace operating on this principle was exhibited at the International Glass Congress in 1932.

The temperature necessary for the melting and plaining of the glass, when the heat is applied by radiation from these resistors, seems to be lower than that required in a gas-fired unit. The author regards this as an apparent difference, caused by the effect of luminous flames on pyrometer readings. The atmosphere of the electric furnace is of course clear, and free from radiating particles.

Another important condition is mentioned, that the temperature gradient between resistors and bath is much less than that between gas-flames and bath. Radiation is so rapid that in practice the resistors are only 50°C. hotter than the glass. Moreover, the time necessary to melt and prepare for working a pot of glass can be cut to 11 hours, as against 15 hours for gas-heating.

The length of the resistors limits the dimensions of the furnace. The longest commercially available being about 5 ft., the free space inside the furnaces cannot well be over 4 ft. in one direction. Several resistors are suspended above and across each open pot. Each resistor forms an independent furnace-unit, thus allowing

* J. Horowitz. Die Glasshütte. 1934. No. 25.
† The Globar Corporation, Niagara Falls, N. Y.
[1] Jour. Amer. Cer. Soc. Vol. 7, p. 764.
[2] Met. & Chem. Eng. Vol. 12, p. 125.
[3] Odelberg, Jour. Amer. Cer. Soc. 1927, p.210-219.

great flexibility in both construction and operation.

Fig. 1 shows a pot-furnace, heated by resistors above and below:

Heat, developed electrically, being an expensive form of energy must be carefully conserved if such furnaces are to economical. This is achieved by elaborate insulation, and by keeping the work-holes closed except during the actual working of the glass. The power required depends so much upon individual conditions of operation, that no general statement of it can be made. The higher melting rate may permit three cycles per 48 hours instead of two, which would bring the cost of heat down to a figure comparable to producer gas at 4 to 5 R. M. per 10^6 Cal. when electricity costs 2 Pf. per Kwh; at an average melting rate. (That is, if electricity cost 0.5c per Kwh., it would compare with natural gas at 25-30c per M.)

In conclusion it can be stated that today the electric glass-melting furnace is on an even footing with the gas-fired furnace, and that this new art of heating deserves consideration when new installations are planned.

LABORATORIES IN GLASS FACTORIES

Is the Installation of Laboratory Productive and Profitable for a Small or Medium-Sized Glass Factory? An editorial writer in "Die Glashutte" answers this question with a decided affirmative, in two recent numbers.

It is not difficult to persuade anyone that the proper control of raw materials, as to composition, purity, calculation of batch, and mixing, is best managed under laboratory supervision.

The laboratory must watch over the glass from here on. The mixing must be thorough. The glass requires critical examination for proper color or decolorizing, for strain, and for adequate resistance to weathering. When shortcomings appear, corrections must be made, to the improvement and cheapening of the batch. Contemporary glasses are examined and compared. The avoidance of waste, and proper salvaging of glass, with rejection of such as cannot profitably be remelted, is distinctly a laboratory function. When the glass fails to work properly, or too great losses occur in processing, it is the laboratory that must find cause and correction.

The confidence of customers is secured by having laboratory examinations made, and treating these complaints impartially on the basis of the findings.

Fuel and heat, and their proper generation and control, are the next subjects assigned. Frequent and regular analyses of producer-gas are great aids to efficient operation. Flue gases are tested and analyzed, to determine whether or not combustion is correct. Leaking flues have been detected, by finding more CO_2 in the producer-gas entering one side of the furnace. Proper repairs restored the furnace to balanced firing.

In the measurement of temperature, regarded as so essential to good factory practice, frequent checking and verification of pyrometers is necessary, if their readings are to be relied upon. Instruments out of adjustment are worse than none at all, because they deceive furnacemen, who might otherwise depend upon their own experienced eyes.

In the annealing process, as well as in melting, correct temperature measurement is vital. There is no other way to establish and repeat the proper cooling cycle for the ware, but by exact knowledge of temperature. Still another unit that should receive the direct attention of the laboratory is the decorating leer. Here it is essential to have not only the proper temperature for developing the decoration, but also sufficiently slow cooling so that the treated ware is well annealed.

The laboratory can be a great aid to the boiler-room. The control of water-softening for the prevention of scale avoids loss from frequent shut-downs and repairs, and saves time and fuel in the generation of steam.

Thus there appear a great number of questions to be answered with the help of the laboratory, whereby the laboratory can demonstrate its worth to the company. A concern that has never had a laboratory cannot estimate how many problems arise in the course of operations, which really require the help of the technologist. The cost is well within the means of any sound company. The running expenses are more than repaid by the services of a properly used laboratory. But proper use means admission of the technical staff to all departments. The mere examination of raw materials is not enough to make it pay. For, when once a reliable source of a given material is found, the detailed examination of every shipment is superfluous. Only those materials should be continually inspected, in which variations are likely to be found. It is by encouraging the chemist and physicist to visit and inspect all departments of the plant, that the greatest use can be made of the laboratory.

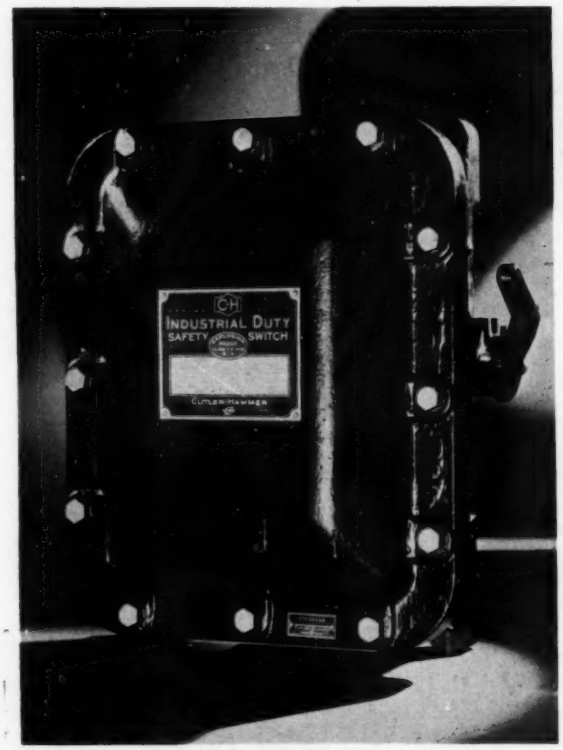
"Here is the duty of the manager, to establish thorough co-operation between the laboratory and the other officials of the plant, in that he calls the chemist into consultation on all problems, and sees to it that the necessary support is given to him from the factory. In the course of time the factory superintendent and other officials will perceive that the factory is best served, if foremen and chemist work together and understand each other. For one thing is clear: that the young chemist, who probably comes to the glass-house direct from college, here as in any other industry finds a number of problems that are strange to him, and he must depend on the support of the foremen. But these latter will also see that the manner in which he attacks the problems laid before him is completely new to them. And if they have a real interest in their calling, they will try to follow the thought-process of the chemist. In time, the plant foremen will acquire an appreciation for the help of the laboratory. When this point is reached, the foundations are laid for a truly productive co-operation between the laboratory and the operating end. Then each division of the plant will come under the conviction that the denizens of the laboratory as well as the executives of the plant belong among the productive workers of a factory, and that each according to his knowledge and skill is working to the same end, to serve the welfare of the plant."

The site of an ancient glass works was recently unearthed by Walter J. Sparks near Suffolk, Va., and it is thought that the plant must have been that of the Bristol Glass Works, dating back to early colonial days. Beautifully cut heads and buttons suggest that Virginia must have been one of four places in the entire world where these objects were made at the time.

EQUIPMENT AND SUPPLIES

EXPLOSION PROOF SAFETY SWITCHES

A new line of explosion proof safety switches for use in Class I, Group D, hazardous locations is announced by Cutler-Hammer, Inc., Milwaukee, Wis. This new line includes both single throw and double throw types, in standard sizes up to 200 amperes capacity.



The switch is a heavy, industrial duty Type A construction, with outside operating handle, mounted in a heavy weather-proof, semi-steel cast enclosure, complying in every respect with requirements of the National Electrical Code. A precision machined flange of required width, between the case and cover, assures proper cooling of any flame which might occur from an explosion within the case, so that outside gases will not ignite. Corrosion resisting bolts hold the cover firmly in place.

Two pipe threaded conduit holes are provided in the bottom of the case and pads at the side and top of the case allow for drilling other holes if needed. Provisions are made for padlocking the handle in either position. It accommodates three padlocks in "off" and three padlocks in "on" positions to meet specific industry requirements. Finish is black Japan.

Descriptive bulletins applying to these switches will be sent on request, by the manufacturer.

The Louis Allis Co. of Milwaukee, Wisconsin, manufacturers of electric motors and similar equipment announce the removal of their Pittsburgh office to 537 Oliver Building. It will be in charge of Mr. J. F. Rodgers.

CATALOGS RECEIVED

Semet-Solvay Piping and Valves. Bulletin No. 44 recently issued by the Semet-Solvay Engineering Corporation, 40 Rector St., New York, describes the Semet-Solvay line of piping and valves for various uses.

Semet-Solvay Gas Producer. In Bulletin No. 45 issued by the above company the operation and construction of the Koller Type Producer is described.

L. & N. Automatic Furnace Pressure Control. The Leeds and Northrup Co., Philadelphia, Pa., have just issued their Bulletin No. 842 which contains a full description of the operation, design, construction and maintenance costs of their recently developed automatic furnace pressure control instruments.

Research Microscopes. Bausch and Lomb Optical Co., Rochester, N. Y. A new catalog, well illustrated, dealing with G. Type Research Microscopes which are available with four types of body tubes, four types of objectives, three types of condensers and four types of eyepieces. The D. D. E. Research and Photomicrographic Microscope is also described and illustrated, as well as several other useful accessories for research microscopes. Enclosed with the catalog is a price list and specifications.

Quarterly Price List. E. I. du Pont de Nemours & Co., Inc., The R. & H. Chemicals Department, Wilmington, Del. A complete price list of R. & H. chemicals for all industries including the important chemicals used in the manufacture of glass.

NEW PUBLICATIONS

Foote-Prints. June, 1934. Published by the Foote Mineral Company of Philadelphia.

This publication contains an article on "Lithium Ores and Salts" in which the sources and uses of amblygonite, spodumine, lepidolite and lithiophylite are illustrated and discussed. It also contains information about the principal salts made from these ores and their use as a batch constituent to impart several valuable properties to certain special glasses.

LYNCH CORPORATION CONSOLIDATES

The consolidation of the plants of the Lynch Corporation from the No. 1 factory at Jackson Street, Anderson, Indiana and the Miller unit from Columbus, Ohio into the new factory at Ames and Crystal Streets in Anderson is now nearly complete. The new factory is thoroughly modern in construction with its saw tooth roof assuring excellent lighting to the workers. The production departments are located in the 100 x 625 foot main building, and the entire plant is sprinklered to reduce fire risk to a minimum.

The transfer of machinery was planned so that there should be no interruption in production. In addition to the machinery from the Anderson and Columbus plants, new equipment has been purchased in order to give the maximum of service to their customers.

COEFFICIENT OF THERMAL EXPANSION OF BORON TRIOXIDE[1]

The interesting results obtained during a study of the heat capacity of boron trioxide lead the above investigators to a study of its other physicochemical properties. The present paper deals with the data obtained in a study of the cubical coefficient of thermal expansion of boron trioxide over a temperature range of 100 to 320°C.

The boron trioxide used was prepared from C. P. anhydrous 99.99 per cent pure B_2O_3 by heating in a platinum crucible for 1-2 hours at 1200° C in order to drive off the last traces of water and to eliminate gas bubbles. The molten oxide was then poured into cylindrical molds and cooled to room temperature over phosphorous pentoxide. The cylinders of B_2O_3 were then turned down in a lath to the desired size.

By using a small dilatometer with mercury as the dilatometric fluid the expansion of several samples were measured over a temperature range of 100 to 320°C; with a probable experimental error of less than 5 per cent. The results obtained on two different samples in various states of annealing are shown in Table 1.

The investigators conclude that the results of this study show that for B_2O_3 the cubical coefficient of thermal expansion in the viscous-liquid state is more than ten times that for the glass and that between these two states there is a transition extending over a temperature range of about 50°C. In view of these findings the investigators believe that a glass must be considered in a separate category from the undercooled viscous liquid from which it is formed. Another noteworthy feature of this study is the very marked influence of the rate of cooling from the liquid to the glassy state. Probably no actual glass can be considered as being in a condition of true thermodynamic equilibrium at a temperature much below its softening region; the attainment of such an equilibrium might require the lapse of almost infinite time.

[1] By M. E. Spaght and G. S. Parks.
Abstracted from the *J. Phys. Chem.* 38, 1, 103-11, (1934).

TABLE I

The Cubical Coefficient of Expansion of B_2O_3

Unannealed		*Partially annealed*		*Carefully annealed*	
Sample I, under various conditions					
°C	α (10^{-4})	°C	α (10^{-4})	°C	α (10^{-4})
113.1	0.41	122.1	0.48	123.7	0.52
139.7	0.37	156.9	0.55	157.4	0.60
166.7	0.17	188.1	0.55	184.4	0.83
193.7	—0.17	213.3	0.83	204.4	1.08
217.8	—0.73	234.8	3.98	222.8	3.45
234.9	2.19	256.6	5.70	247.5	5.61
251.1	5.84	286.5	6.25	275.7	6.05
269.1	6.00				
290.3	6.16				
310.0	5.84				
Sample 2, under various conditions					
122.1	0.40	120.6	0.56	114.2	0.54
152.3	0.19	152.9	0.59	143.4	0.49
180.4	—0.19	177.8	0.71	171.8	0.59
204.9	—1.07	193.8	0.85	199.6	1.18
229.4	0.55	217.1	1.62	226.9	4.35
250.2	4.10	233.1	4.64	250.0	6.13
270.0	6.22	249.1	6.64	270.0	5.92
293.8	6.35				

POLISHED PLATE PRODUCTION

The total production of Polished Plate Glass by the member Companies of the Association for the month of June 1934 was 6,520,081 sq. ft., as compared to 7,764,477 sq. ft. produced by the same Companies in the preceding month, May 1934, and 9,499,260 sq. ft. produced in the corresponding month last year, June 1933.

This makes a total of 47,889,271 sq. ft. produced by these Companies during the first six months of 1934, as compared to 38,126,348 sq. ft. produced by the Association members during the first six months of 1933, and 47,911,457 sq. ft. in the last half of that year.

ANCHOR CAP TO ACQUIRE SALEM

A special stockholders' meeting of Anchor Cap Corporation was called for July 27 to take action upon an increase in authorized capital stock in connection with the acquisition of Salem Glass Works at Salem, N. J.

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CURRENT PRICES OF GLASS-MAKING MATERIALS

FURNISHED BY PRODUCERS, MANUFACTURERS AND DEALERS

		Carlots	Less Carlots
Acid			
Citric (dom.)	lb.	...	.29
Hydrochloric (HCl) 20° tanks	Per 100 lb.	...	1.10
Hydrofluoric (HF) 60% (lead carboy)	lb.	...	.13½
52% and 48%	lb.	.10	.10-.11½
Nitric (HNO_3) 38° carboy ext.	Per 100 lb.	5.50	...
Sulphuric (H_2SO_4) 66° tank cars	ton	15.50	...
Tartaric	lb.	...	Po. or Gr. .25 / Cry. .25½
Alcohol, denatured	gal.	...	...
Aluminum hydrate ($Al(OH)_3$)	lb.	.04-.04½	.04½-.05
Aluminum oxide (Al_2O_3)	lb.	.04	.05
Ammonium bicarbonate (f.o.b. works)	lb.	.05¼	...
(f.o.b. N. Y.)	lb.	...	.0571
Ammonium bifluoride (NH_4FHF)	lb.	...	.15
Ammonia water (NH_4OH) 26° drums	lb.	...	.02¾
Antimonate of Sodium	lb.	...	.10
Antimony, metallic (Sb)	lb.	.02½	.02¾
Antimony oxide (Sb_2O_3)	lb.	...	.09
Antimony sulphide (Sb_2Sa)	lb.	...	.07
Arsenic trioxide (As_2O_3) (dense white) 99%	lb.	.04	.04½
Barium carbonate ($BaCO_3$), Crude, (Witherite) 90%, 99% through 200 mesh	ton	56.50	61.50
90% through 100 mesh	ton	44.00	...
Barium hydrate ($Ba(OH)_2$)	lb.	.05	.05¾
Barium nitrate ($Ba(NO_3)_2$)	lb.	...	.08¾
Barium selenite ($BaSeO_3$)	lb.	...	1.50-1.75
Barium sulphate, in bags	ton	19.00	24.00
Barium sulphate, glassmaker's, carlots, bulk f. o. b. shipping point	ton	15.00-16.00	18.00
Bone ash	lb.	.06	.06½
Borax ($Na_2B_4O_7 10H_2O$)	lb.	...	...
Granulated	In bags, lb.	.02	.02¼-.02½
Powdered	In bags, lb.	.02¼	.02½-.02¾
Boric acid (H_3BO_3) granulated	In bags, lb.	.04¼	.04½-.04¾
Cadmium sulphide (CdS)—	lb.	...	.70-.75
Chromite	lb.	...	.215
Chrome oxide Green	lb.	...	.215-.25
Cobalt oxide (Co_2O_3)			
In bbls.	lb	...	1.25
In 10 lb. tins	lb.	...	1.35
Copper oxide			
Red (Cu_2O)	lb.	...	.25
Black (CuO)	lb.	...	.17-.19
Black prepared	lb.	...	.22
Cryolite ($Na_3Al\ F_6$) Natural Greenland (Kryolith)	lb.	.08½	.09
Synthetic (Artificial)	lb.	.08-.085	.085-.09
Epsom salts ($MgSO_4$) (imported) technical	Per 100 lb.	...	2.40
Feldspar—			
40 mesh	ton	10.50-12.75	
20 mesh	ton	10.00-12.25	
Granular	ton	10.75-13.00	
Semi-granular	ton	10.00-12.25	
L. C. L., (Min. 2 tons) $3.00 per ton additional plus charge for bags			
Fluorspar (CaF_2) domestic, ground, 96-98% (max SiO_2, 2½%)			
Bulk, carloads, f. o. b. mines	ton	35.00	...
In bags	ton	36.60	40.60
Imported (f.o.b. Seaboard)	ton	31.00	...
Formaldehyde	lb.	.05	.07
Graphite (C)	lb.	...	.04-.07
Iron oxide—			
Red (Fe_2O_3)	lb.	...	.0425
Black ($Fe3O_4$)	lb.	.04½	...
Iron chromate	lb.	...	.035-.05
Kaolin (f. o. b. mine)	ton	8.00-9.00	...
English, lump, f. o. b. New York	ton	14.50-25.00	24.50-30.00
Kryolith (see Cryolite)			
Lead chromate ($PbCrO_4$)	lb.	...	.16
Lead oxide (Pb_3O_4) (red lead)	lb.	.063-.0635	...
In 5 Ton lots	lb.	...	.0675
Less than 5 Tons	lb.	...	.0725
Litharge (PbO)	lb.	.053-.0535	...
In 5 Ton lots	lb.	...	.0575
Less than 5 Tons	lb.	...	.0625
Lime—			
Hydrated ($Ca(OH)_2$) (in paper sacks)	ton	10.50	...
Burnt (CaO) ground, in bulk	ton	7.00	...
Burnt, ground, in paper sacks	ton	9.00	...
Burnt, ground, in 280 lb. bbls.	Per bbl.	2.15	2.30
Limestone ($CaCO_3$)		1.75-2.50	...
Magnesium carbonate ($MgCO_3$)	lb.	.06	.08-.09
Magnesium sulphate (U.S.P.)	lb.	...	.03
Manganese, Black Oxide			
In Paper bags	ton	45.00	...
In Burlap bags	ton	46.50	51.50
In Casks	ton	48.00	53.00
Nickel oxide (Ni_2O_3), black— for nickel content	lb.	...	.35-.40
Nickel monoxide (NiO), green— for nickel content	lb.	...	.35-.40
Plaster of Paris, bags	ton	31.00	23.00-29.00
Potassium bichromate ($K_2Cr_2O_7$)—			
Crystals	lb.	.08½	.08⅝
Powdered	lb.	.08⅝	.09⅛
Potassium carbonate	lb.	.0825	.0875
Calcined (K_2CO_3) 96-98%	lb.	.07⅞	.0875
Hydrated 80-85%	lb.	.07¼	.0775
Potassium chromate (K_2CrO_4)	lb.		.14¼
Potassium hydrate (KOH) (caustic potash)	lb.	.07½	.09
Potassium nitrate (KNO_3) (gran.)	lb.	...	.06-.06¼
Potassium permanganate ($KMnO_4$)	lb.	...	.19
Powder blue	lb.	...	.17-.18
Rochelle salts, bbls	lb.	...	.12½
Rouge	lb.	...	Po. or Gr. .13½ / Cry.
Rutile (TiO_2) powdered, 95%	lb.	.15-.20	.20-.25
Salt cake, glassmakers (Na_2SO_4)	ton	18.00	27.00
Selenium (Se)	lb.	...	1.80-2.00
Silver nitrate (AgNO)	(100 oz.) per oz.	...	.33½
Soda ash (Na_2CO_3) dense, 58%—			
Bulk	Flat Per 100 lb.	1.10	...
In barrels	Per 100 lb.	1.50	...
In bags	Per 100 lb.	1.25	...
Sodium bichromate ($Na_2Cr_2O_7$)	lb.	...	.06⅝
Sodium fluosilicate (Na_2SiF_6)	lb.	...	.05-.06
Sodium hydrate (NaOH) (caustic soda)			
Flake	Per 100 lb.	3.00	...
Solid	Per 100 lb.	2.60	...
Sodium nitrate ($NaNO_3$)—			
Refined (gran.) in bbls	lb.	...	2.25-2.50
95% and 97%			
Bulk	Per 100 lb.	1.225	...
200 lb bags		1.315	1.365
100 lb. bags		1.35	1.40
Sodium selenite (Na_2SeO_3)	lb.	..	1.80-2.00
Sodium uranate (Na_2UO_4) Yellow or Orange	lb.	...	1.50-1.55
Sodium uranyl carbonate	lb.	...	.80-.90
Sulphur (S)—			
Flowers, in bbls	Per 100 lb.	3.45	3.70-4.05
Flowers, in bags	Per 100 lb.	3.10	3.35-3.65
Flour, heavy, in bbls	Per 100 lb.	2.85	3.20-3.45
Tin chloride ($SnCl_2$) (crystals) in bbls.	lb.	...	.385
Tin oxide (SnO_2) in bbls	lb.	...	.57-.60
Uranium oxide (UO_2) (black, 96% U_3O_8) 100 lb. lots. Black	lb.	...	2.75
Yellow orange	lb.	...	1.55
Zinc oxide (ZnO) (Red Seal)	lb.	.09½	.09⅝
American process, Bags	lb.	.065	.0675
White Seal, 150 lb. bbls.	lb.	.10⅝	.10⅞
Green Seal bags	lb.	.09⅝	.09⅝
Red Seal, bags	lb.	.08⅝	.08⅝
Zircon			
Granular (Milled .005-.02c higher)		.07	.67½-.08
Crude, Gran. (Milled .005-.02c higher)		.03½	.04-.05

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